

Assessment Report: Biological Impairment in the Upper Conetoe Creek Watershed

Tar Pamlico River Basin
Edgecombe, Martin and Pitt Counties, N.C.

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Executive Summary

Introduction

This report presents the results of the upper Conetoe Creek water quality assessment, conducted by the North Carolina Division of Water Quality (DWQ) with financing from the Clean Water Management Trust Fund (CWMTF). Conetoe Creek is considered impaired by the DWQ because it is unable to sustain an acceptable community of aquatic organisms, indicating that the stream does not fully support its designated uses. The goal of the assessment is to provide the foundation for future water quality restoration activities in the Conetoe Creek watershed by: 1) identifying the most likely causes of biological impairment; 2) identifying the major watershed activities and pollution sources contributing to those causes; and 3) outlining a general watershed strategy that recommends restoration activities and best management practices (BMPs) to address the identified problems.

Study Area and Stream Description

Conetoe Creek drains a 108-square mile watershed in Edgecombe, Pitt and Martin Counties in the Tar-Pamlico River basin, subbasin 03-03-03 (see Figure 1.1). The area studied consists of Conetoe Creek and its major tributaries (Ballahack Canal, Crisp Creek and Fountain Fork Creek) upstream of the US Geological Survey gaging station at SR 1409 (station 02083800).

Approximately three quarters of the 78-square mile study area is located in Edgecombe County. The watershed is heavily agricultural, with several swine operations and about 40% of the area in row crops (cotton, soybeans, peanuts and corn). The area is sparsely populated and includes the small Town of Conetoe and portions of Bethel. The Bethel wastewater treatment plant discharges to Coneote Creek within the study area.

Streams in the study area have been channelized (dredged and straightened) on a number of occasions over the last several centuries to increase drainage on watershed lands and expand the area available for agricultural production. This occurred most recently in the 1960s, when 95 miles of stream in the watershed were dredged and straightened. Channels today are straight, uniform and deeply incised. Streams are subject to periodic clearing and snagging operations and intermittently dredged. The study area is described in more detail in Section 2.

Streams in the watershed are classified as CNSW. Benthic macroinvertebrate communities are impaired throughout the mainstem of Conetoe Creek within the study area, as well as in Crisp Creek and Ballahack Canal. Sensitive organisms are generally not found in the watershed and at some locations benthic organisms of any type are sparse. Habitat is generally poor, with a lack of large woody debris and other organic habitat necessary to provide structure in coastal plain streams.

Approach

A wide range of data was collected to evaluate potential causes and sources of impairment. Data collection activities included: benthic macroinvertebrate sampling; assessment of stream habitat, morphology and riparian zone condition; water quality sampling to evaluate stream chemistry and toxicity; sediment sampling; characterization of watershed land use, conditions and pollution sources. Data collected during the study are presented in Sections 2, 4, 5 and 6 of the report.

Conclusions

- Aquatic organisms in upper Conetoe Creek are heavily impacted by three critical stressors: toxic impacts, habitat degradation and low dissolved oxygen levels (due at least in part to high nutrient and organic loading). The impact of each of these stressors appears to be severe, and the presence of any one of them at current levels may be sufficient to cause substantial degradation in biological condition.
- Agricultural chemicals are the only credible widespread source of potential toxicants in the study area, although the available information is not sufficient to evaluate which specific pesticides are most critical, or which pathways of pesticide delivery to waterbodies are most important.
- The poor habitat condition is attributable to the channelized nature of Conetoe Creek and its tributaries and to a major clearing and snagging operation carried out during the year prior to the study.
- Sources of nutrient loading to Conetoe Creek appear to be widespread, most likely coming primarily from numerous agricultural operations.
- While it is likely that lower than normal streamflows had some impact on the conditions observed during this study, it is not likely that the impoverished state of stream biota can be attributed entirely or primarily to drought. Other watersheds in eastern North Carolina have retained more diverse benthic communities than Conetoe Creek despite below normal precipitation over the past several years.

Recommendations

The following actions are necessary to address current sources of impairment in Conetoe Creek. The intent of these recommendations is to describe the types of actions necessary to improve conditions in the Conetoe Creek watershed, not to specify particular administrative or institutional mechanisms for implementing remedial practices.

1. The appropriate agricultural agencies (including the NC Department of Agriculture and Consumer Services, the NC Division of Soil and Water Conservation, local Soil and Water Conservation Districts, and the US Department of Agriculture Natural Resources Conservation Service), in cooperation with university researchers (e.g., the NCSU Cooperative Extension Service), local farmers and DWQ, should evaluate current pesticide usage and application practices in order to better understand the dimensions of pesticide impacts in the Conetoe Creek watershed. The results of this investigation, which may require additional water sampling, should be used to determine what specific actions are necessary to reduce pesticide impacts.
2. Future clearing and snagging operations should generally be confined to removing major blockages of the stream channel. Edgecombe County Drainage District #2, NRCS and DWQ should work to develop clearing and snagging guidelines for Conetoe Creek that will provide for improved in-stream habitat while still ensuring adequate drainage. Training and oversight of contractors should be one component of this effort.
3. For any clearing and snagging operations requiring a Section 401 Water Quality Certification (necessary where a Section 404 permit is required from the US Army Corps of Engineers), DWQ will closely examine potential impacts on aquatic habitat and work to ensure that these impacts are minimized.
4. The reestablishment of woody riparian vegetation (or herbaceous cover where woody vegetation is impractical) should be encouraged along intermittent and perennial streams

where such vegetation is currently lacking. In addition to supplying woody material to the stream, properly functioning riparian areas can also serve to reduce inputs of nutrients and other pollutants. Ballahack Canal, which has the most impacted riparian areas in the study area, should be a priority area for these efforts in order to ensure an adequate supply of woody material to this tributary stream. Establishment of forested riparian buffers would receive substantial nutrient reduction credit under the Tar-Pamlico agriculture rule and is a cost shared practice under several programs.

5. Nutrient reduction efforts in the Conetoe Creek watershed will proceed most efficiently if they are coordinated with the ongoing efforts to reduce nutrients under the Tar-Pamlico Agriculture Rule. The Local Advisory Committees (LACs) responsible for implementing this rule in Edgecombe, Pitt and Martin Counties should give the Conetoe Creek watershed priority status for the implementation of nutrient reduction measures.
6. The LACs within the Conetoe Creek watershed will be developing specific nutrient reduction strategies by August 2003 to meet goals under the Tar-Pamlico Agriculture Rule. While DWQ does not wish to short circuit this process, it is important that the LACs operative in the Conetoe Creek watershed consider the following factors in developing nutrient strategies:
 - Many field ditches in the watershed lack adequate vegetative buffers. Increased use of vegetative filter strips, riparian herbaceous cover, field borders or other practices along these ditches would have a high potential for reducing nutrient inputs. Riparian forest buffers, where they would not impede irrigation practices, would both provide greater nutrient removal than herbaceous buffering practices and serve as a source of woody debris for channel habitat. Cost share is available for all of these practices.
 - The use of controlled drainage is common in the watershed, but the manner in which these structures are managed merits evaluation to determine if opportunities exist to improve water management in order to reduce nutrient exports that are compatible with agricultural production goals.
 - The short-term rental of much of the cultivated land in the study area may be a disincentive for the implementation of some BMPs and will need to be addressed. Outreach efforts to educate landowners regarding the importance of nutrient management and environmental stewardship more generally should be encouraged and supported. For some structural BMPs, it may be important for LACs to provide guidance to renters on the types of arrangements to establish with owners, for example arrangements similar to those used in permanent agreements under CREP (Conservation Reserve Enhancement Program).
7. On-stream impoundments and irrigation withdrawals may exacerbate the impacts of nutrient and organic loading on dissolved oxygen levels in Conetoe Creek. The construction of new on-stream impoundments and the withdrawal of additional irrigation water should be discouraged until a study of the impacts of these activities on streamflows and dissolved oxygen levels can be completed.

Section 1

Introduction

This report presents the results of the upper Conetoe Creek water quality assessment, conducted by the North Carolina Division of Water Quality (DWQ) during 2001 and 2002 with financing from the Clean Water Management Trust Fund (CWMTF). Conetoe Creek is considered impaired by the DWQ because it is unable to support an acceptable community of aquatic organisms. The reasons for this condition have been previously unknown, inhibiting efforts to improve stream integrity in this watershed.

Part of a larger effort to assess impaired streams across North Carolina, this study was intended to evaluate the causes of biological impairment and to suggest appropriate actions to improve stream conditions. The CWMTF, which allocates grants to support voluntary efforts to address water quality problems, is seeking DWQ's recommendations regarding the types of activities it could fund to improve water quality in these watersheds. Both the DWQ and the CWMTF are committed to encouraging local initiatives to protect streams and to restore degraded waters.

1.1 Study Area Description

Conetoe Creek is located in Edgecombe, Pitt and Martin Counties and the Tar-Pamlico River basin (Figure 1.1), draining a 108-square mile watershed. The stream begins in Edgecombe County, approximately 1.5 miles south of the Town of Speed, and flows southward through Edgecombe County and Pitt County to meet the Tar River near Falkland, NC.

The 78-square mile study watershed includes all portions of Conetoe Creek, Fountain Fork Creek, Crisp Creek, Ballahack Canal and other tributaries located upstream of the US Geological Survey (USGS) gaging station at SR 1409 (station 02083800), 5.5 miles west of Bethel in Pitt County. Conetoe Creek is considered impaired from its source to SR 1404 in Pitt County (downstream of the study area), a distance of approximately 15.4 miles. The study area is rural and sparsely populated. Land use is primarily agricultural and includes both row crops and animal operations. The only permitted wastewater discharge in the study area is the Town of Bethel wastewater treatment plant (WWTP) located on Conetoe Creek in the downstream part of the study area. The watershed lies in DWQ subbasin 03-03-03. Streams in the watershed are classified as CNSW.

1.2 Study Purpose

The Conetoe Creek assessment is part of the Watershed Assessment and Restoration Project (WARP), a study of eleven watersheds across the state being conducted with funding from the CWMTF (Table 1.1). The goal of the project is to provide the foundation for future water quality restoration activities in the eleven watersheds by:

1. Identifying the most likely *causes* of biological impairment (such as degraded habitat or specific pollutants).

2. Identifying the major watershed activities and *sources* of pollution contributing to those causes (such as stream bank erosion or stormwater runoff from particular urban or rural areas).
3. Outlining a watershed *strategy* that recommends restoration activities and best management practices (BMPs) to address the identified problems and improve the biological condition of the impaired streams.

This investigation focused primarily on aquatic life use support issues. It was intended to assess the major issues related to biological impairment as comprehensively as possible within the time frame of the study. While not designed to address other important issues in the Coneote Creek watershed, such as bacterial contamination or flooding, the report discusses those concerns where existing information allows.

Table 1.1 Study Areas Included in the Watershed Assessment and Restoration Project

Watershed	River Basin	County
Toms Creek	Neuse	Wake
Upper Swift Creek	Neuse	Wake
Little Creek	Cape Fear	Orange, Durham
Horsepen Creek	Cape Fear	Guilford
Little Troublesome Creek	Cape Fear	Rockingham
Upper Clark Creek	Catawba	Catawba
Upper Cullasaja River/Mill Creek	Little Tennessee	Macon
Morgan Mill/Peter Weaver Creeks	French Broad	Transylvania
Mud Creek	French Broad	Henderson
Upper Coneote Creek	Tar-Pamlico	Edgecombe, Pitt, Martin
Stoney Creek	Neuse	Wayne



Background Note: Identifying Causes of Impairment

Degradation and impairment are not synonymous. Many streams and other waterbodies exhibit some degree of degradation, that is, a decline from unimpacted conditions. Streams that are no longer pristine may still support good water quality conditions and function well ecologically. When monitoring indicates that degradation has become severe enough to significantly interfere with one of a waterbody's designated uses (such as aquatic life propagation or water supply), the Division of Water Quality formally designates that stream segment as impaired. It is then included on the state's 303(d) list, the list of impaired waters in North Carolina.

Many impaired streams, including those that are the subject of this study, are so rated because they do not support a healthy population of fish or benthic macroinvertebrates (aquatic 'bugs' visible to the naked eye). While standard biological sampling can determine whether a stream is supporting aquatic life or is impaired, the cause of impairment can only be determined with additional investigation. In some cases, a potential cause of impairment is noted when a stream is placed on the 303(d) list, using the best information available at that time. These noted potential causes are generally uncertain, especially when nonpoint source pollution issues are involved.

A cause of impairment can be viewed most simply as a stressor or agent that actually impairs aquatic life. These causes may fall into one of two broad classes: 1) chemical or physical pollutants (e.g., toxic chemicals, nutrient inputs, oxygen-consuming wastes); and 2) habitat degradation (e.g., loss of in-stream structure such as riffles and pools due to sedimentation; loss of bank and root mass habitat due to channel erosion or incision). Sources of impairment are the origins of such stressors. Examples include urban and agricultural runoff.

The US Environmental Protection Agency defines causes of impairment more specifically as "those pollutants and other stressors that contribute to the impairment of designated uses in a waterbody" (USEPA, 1997, pp. 1-10). When a stream or other waterbody is unable to support an adequate population of fish or macroinvertebrates, identification of the causes of impairment thus involves a determination of the factors most likely leading to the unacceptable biological conditions.

All conditions which impose stress on aquatic communities may not be causes of impairment. Some stressors may occur at an intensity, frequency and duration that are not severe enough to result in significant degradation of biological or water quality conditions to result in impairment. In some cases, a single factor may have such a substantial impact that it is the only cause of impairment, or clearly predominates over other causes. In other situations, several major causes of impairment may be present, each with a clearly significant effect. In many cases, individual factors with predominant impacts on aquatic life may not be identifiable and the impairment may be due to the cumulative impact of multiple stressors, none of which is severe enough to cause impairment on its own.

The difficulty of developing linkages between cause and effect in water quality assessments is widely recognized (Fox, 1991; USEPA, 2000). Identifying the magnitude of a particular stressor is often complex. Storm-driven pollutant inputs, for instance, are both episodic and highly variable, depending upon precipitation timing and intensity, seasonal factors and specific watershed activities. It is even more challenging to distinguish between those stressors which are present, but not of primary importance, and those which appear to be the underlying causes of impairment. Following are examples of issues which must often be addressed.

- Layered impacts (Yoder and Rankin, 1995) may occur, with the severity of one agent masking other problems that cannot be identified until the first one is addressed.
- Cumulative impacts, which are increasingly likely as the variety and intensity of human activity increase in a watershed, are widely acknowledged to be very difficult to evaluate given the current state of scientific knowledge (Burton and Pitt, 2001; Foran and Ferenc, 1999).
- In addition to imposing specific stresses upon aquatic communities, watershed activities can also inhibit the recovery mechanisms normally used by organisms to 'bounce back' from disturbances.

For further information on use support and stream impairment issues, see the website of DWQ's Basinwide Planning Program at <http://h2o.enr.state.nc.us/basinwide/>; *A Citizen's Guide to Water Quality Management in North Carolina* (NCDWQ, 2000); EPA's *Stressor Identification Guidance Document* (USEPA, 2000).

1.3 Study Approach and Scope

Of the study's three objectives, identification of the likely causes of impairment is a critical building block, since addressing subsequent objectives depends on this step (Figure 1.2). Determining the primary factors causing biological impairment is a significant undertaking that must address a variety of issues (see the Background Note "Identifying Causes of Impairment"). While identifying causes of impairment can be attempted using rapid screening level assessments, this study has taken a more detailed approach in order to maximize the opportunity to reliably and defensibly identify causes and sources of impairment within the time and resource framework of the project. This provides a firmer scientific foundation for the collection and evaluation of evidence, facilitates the prioritization of problems for management, and offers a more robust basis for the commitment of resources. EPA's recently published guidance for stressor identification envisions that causes of impairment be evaluated in as rigorous a fashion as is practicable (USEPA, 2000).

1.3.1 Study Approach

The general conceptual approach used to determine causes of impairment in Conetoe Creek was as follows (see Foran and Ferenc, 1999; USEPA, 2000).

- *Identify the most plausible potential (candidate) causes* of impairment in the watershed, based upon existing data and initial watershed reconnaissance activities.
- *Collect data* bearing on the nature and impacts of those potential causes.
- *Characterize the causes of impairment* by evaluating all available information using a *strength of evidence approach*. The strength of evidence approach, discussed in more detail in Section 7, involves a logical evaluation of multiple lines (types) of evidence to assess what information supports or does not support the likelihood that each candidate stressor is actually a contributor to impairment.

Project goals extended beyond identifying causes of impairment, however, and included the evaluation of source activities and the development of recommendations to mitigate the problems identified. In order to address all three objectives, activities conducted in the upper Conetoe Creek watershed during this study were divided into three broad stages (Figure 1.2):

1. An initial *reconnaissance stage*, in which existing information was compiled and watershed reconnaissance conducted. At the conclusion of this stage, the most plausible candidate causes of impairment were identified for further evaluation.
2. A *stressor-source evaluation stage* that included: collection of information regarding candidate causes of impairment; evaluation of all available information using a strength of evidence approach; investigation of likely sources (origins) of the critical stressors.
3. The *development of strategies* to address the identified causes of impairment.

1.3.2 Approach to Management Recommendations

One of the goals of this assessment was to outline a course of action to address the key problems identified during the investigation, providing local stakeholders, the CWMTF and others with the

information needed to move forward with targeted water quality improvement efforts in this watershed. It is DWQ's intent that the recommendations included in this document provide guidance that is as specific as possible given available information and the nature of the issues to be addressed. Where problems are multifaceted and have occurred over a long period of time, the state of scientific understanding may not permit all actions necessary to mitigate those impacts to be identified in advance. In such situations, an iterative process of 'adaptive management' (Reckhow, 1997; USEPA, 2001) is required, in which those committed to stream improvement efforts begin with implementation of an initial round of management actions, followed by monitoring to determine what additional measures are needed.

Protection of streams from additional damage due to future watershed development or other planned activities is a critical consideration. In the absence of such protection, efforts to restore water quality by mitigating existing impacts will often be ineffective or have only a temporary impact. These issues were examined during the course of the study and addressed in the management recommendations.

It is not the objective of this study to specify particular administrative or institutional mechanisms for implementing remedial practices, but only to describe the types of actions that must occur to place Conetoe Creek on the road to improvement. It is DWQ's hope that local governments and other stakeholders in the Conetoe Creek watershed will work cooperatively with each other and with state agencies to implement these measures in cost-effective ways.

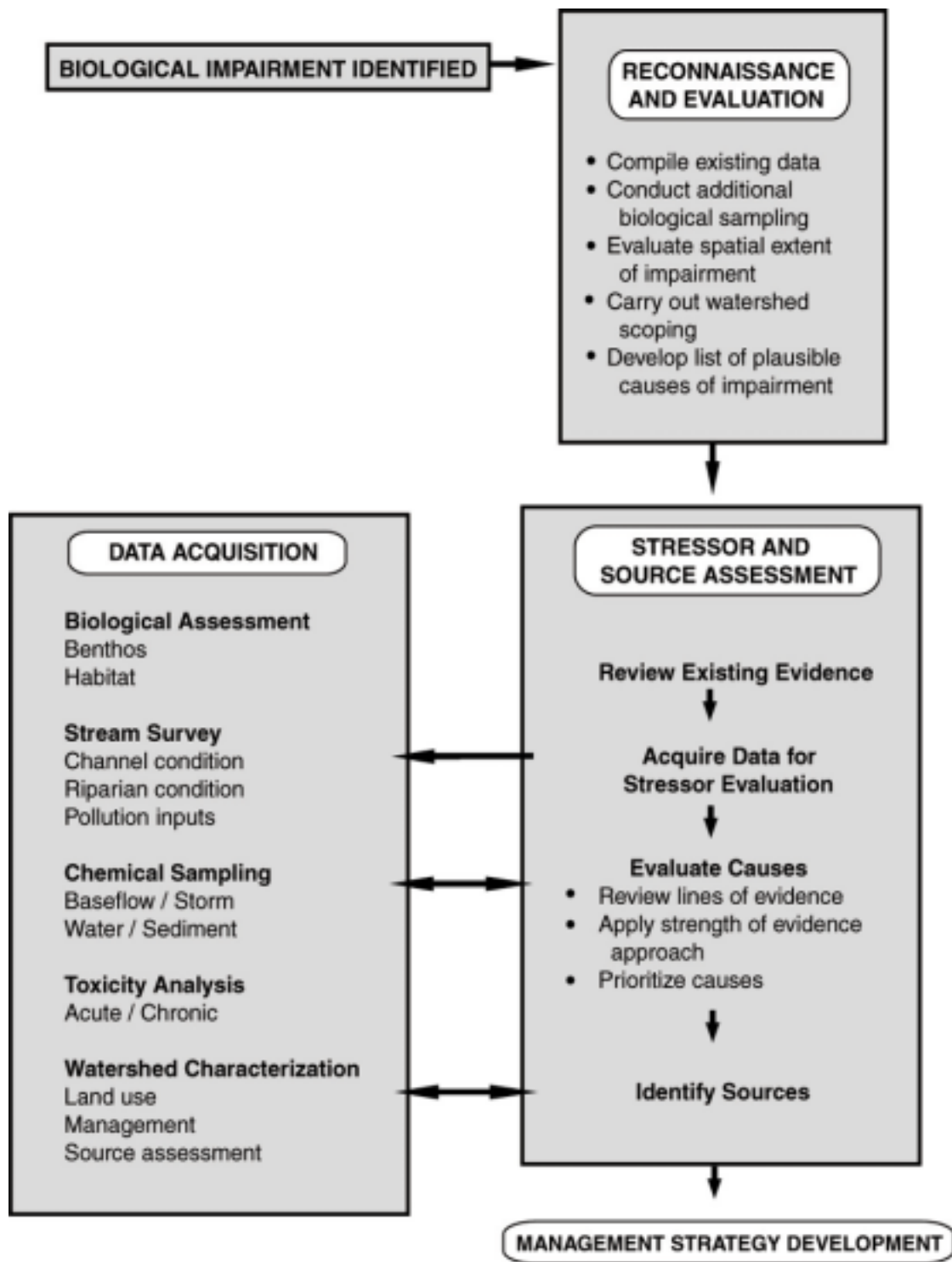
The study did not develop TMDLs (total maximum daily loads) or establish pollutant loading targets. For many types of problems (e.g., most types of habitat degradation), TMDLs may not be an appropriate mechanism for initiating water quality improvement. Where specific pollutants are identified as causes of impairment, TMDLs may be appropriate and necessary if the problem is not otherwise addressed expeditiously.

1.3.3 Data Acquisition

While project staff made use of existing data sources during the course of the study, these were not adequate to fully address the goals of the investigation. Extensive data collection was necessary to develop a more adequate base of information. The types of data collected during the study included:

1. Macroinvertebrate sampling.
2. Assessment of stream habitat, morphology and riparian zone condition.
3. Stream surveys--walking stream channels to identify potential pollution inputs and obtain a broad scale perspective on channel condition.
4. Chemical sampling of stream water quality.
5. Bioassays to assess water column toxicity.
6. Chemical sampling and bioassays of stream sediment.
7. Watershed characterization--evaluation of watershed hydrologic conditions, land use, land management activities, and potential pollution sources.

Figure 1.2 Overview of Study



Section 2

Description of the Conetoe Creek Watershed

2.1 Introduction

The study area (Figure 1.1) consists of Conetoe Creek and its tributaries upstream of the USGS gaging station at SR 1409, located 5.5 miles west of Bethel. The 78-square mile study area represents approximately 72% of the entire Conetoe Creek watershed. Approximately 75% of the study area is located in Edgecombe County, 15% in Pitt County and 10% in Martin County. This section summarizes watershed hydrology, geology and topography, describes current and historical land use, and discusses potential pollutant sources.

2.2 Streams and Hydrology

The mainstem of Conetoe Creek in the study area (Figure 2.1) is joined by the following major tributaries, in order from upstream to downstream: Fountain Fork Creek, Crisp Creek and Ballahack Canal. Conetoe Creek and its tributaries are classified by the State of North Carolina as C-NSW (nutrient sensitive waters). North Carolina's 2000 303(d) list records Conetoe Creek as biologically impaired from its source to SR 1404 in Pitt County, downstream of the study area. The reasons for biological impairment had not been determined prior to the study. Suspected causes of impairment noted on the 303(d) list include municipal point source pollution, crop production and channelization.

Typical Coastal Plain features such as slow flowing, blackwater streams and low lying swamplands with extensive bottomland forests and marsh floodplains characterize the Conetoe Creek watershed. All streams in the study watershed have been extensively channelized (dredged and straightened) to improve drainage of agricultural lands and provide the streamflows required for irrigation (Exhibit 2.1).

Agricultural fields in the study area have been ditched to improve drainage (Exhibit 2.2). Field ditches drain to larger ditches, known as laterals, and laterals drain to the mainstem or tributaries. Ditches are typically unbuffered or poorly buffered and lie directly adjacent to row crops. Streams are routinely subject to clearing and snagging operations (removal of logs, branches and other woody debris), and dredging is repeated as needed to maintain channels. Extensive snagging to clear waterways after Hurricane Floyd (September 1999) was completed by the Natural Resources Conservation Service in September 2000.

There are a number of impoundments on the mainstem of Conetoe Creek and its major tributaries (Exhibits 2.3 and 2.4). The dams are generally confined to the stream channel, creating extensive backwater but not impounding areas outside of the channel. Most were constructed to facilitate irrigation withdrawals. According to the NC Division of Water Resources, two farms on Conetoe Creek are registered to withdraw over one million gallons per day (MGD) for irrigation. One of these withdraws an average of 1.357 MGD and the other withdraws an average of 0.504 MGD. Local NRCS personnel (Mr. A.B. Whitley, Edgecombe County, personal communication) estimate that withdrawals below the one MGD registration

threshold occur at approximately two dozen sites in the Conetoe Creek watershed. Many of these sites may not be located in the study area, but a precise number is not available and the location of these sites varies. The cumulative amount of these unregistered withdrawals is not known.



Exhibit 2.1 Typical Conetoe Creek channel section



Exhibit 2.2 Field ditch in the Conetoe Creek watershed



Exhibit 2.3 Dam on Conetoe Creek, downstream of SR 1409



Exhibit 2.4 Dam on Ballahack Canal near NC 42

Precipitation at the nearby weather station in Tarboro averages 45.7 inches per year (source: Southeast Regional Climate Center). Although precipitation is distributed fairly evenly throughout the year, streamflows are lowest in summer and early fall due to evapotranspiration during the warm growing season. Because thunderstorms account for a large portion of rainfall during this period, some areas may be without significant rainfall for five to 20 days, while nearby locations experience substantial precipitation and runoff.

From 1956 until October 2001, the United States Geological Survey (USGS) operated a continuous gage on Conetoe Creek at 1409 (station 02083800), 5.5 miles downstream of Crisp Creek. The quality of the record is described as poor (Ragland et al., 2002). According to DWQ Raleigh Regional Office staff, the Town of Bethel and the USGS, measurements from April to September are unpredictable due to a semi-permeable dam located one-half mile downstream of the gaging station (Exhibit 2.3). Because of this problem, the USGS has been unable to determine streamflow at the station after October 1, 2001. The gage was moved upstream to US 64 Business in July 2002. The Town of Bethel WWTP determines permitted discharge periods based on streamflow at the gage (see discussion below). This gage station will remain active until Bethel connects to Greenville's wastewater facilities and discontinues its discharge into Conetoe Creek. Stream discharge data are currently not available for the period since September 30, 2001. Discharge data for the current gage location and discharge estimates for the remaining period at the SR 1409 site will be available by April 2003.

Hurricanes Fran (September 1996) and Floyd (September 1999) resulted in severe flooding, with streamflows recorded during Hurricane Floyd the highest on record. More recently, drought conditions have prevailed. Average discharge was near normal during water year 2000 (Table 2.1), but less than one-half normal levels during 2001, when much of the benthic sampling was conducted (Section 4). During calendar year 2001 (through September), stream discharge was below average for every month except June (see chart in Appendix A). Stream discharge data are not available for 2002, as discussed above. Precipitation in Tarboro was 79% of normal from January to July 2002, although records are incomplete for some months (source: Southeast Regional Climate Center at <http://www.sercc.com/products/monthly/monthly.html>).

Table 2.1 Average Annual Discharge in Conetoe Creek (Station 02083800)

Water Year*	Annual Mean Discharge (cfs)
2000	75.6
2001	38.4
1957-2001	79.7

* A water year includes Jan.-Sept. of the year listed and Oct.-Dec. of the previous year.

2.3 Topography and Soils

Topographic relief in the study area is limited. Elevations range from 26 feet above mean sea level in the upper portion of the watershed to 14 feet in power portions. Gradients rarely exceed four percent and the majority of the watershed is nearly level.

Floodplain soils in Edgecombe County, other than those adjacent to Fountain Fork Creek, are of the Bibb-Johnston Association (Goodwin, 1979). These soils are poor to very poorly drained and have loamy and sandy underlying material. Soils in the floodplain of Fountain Fork Creek and in upland areas, adjacent to floodplains, are of the Norfolk-Aycock-Wagram Association. These soils are poorly drained to excessively poorly drained with loamy underlying material. Soils in upland areas, not bordering floodplains, are of the Goldsboro-Rains Association and the Roanoke-Conetoe-Portsmouth Association, well drained to poorly drained soils. Soils in Pitt County within the study area are primarily of the Norfolk-Exum-Goldsboro Association (USDA, 1974).

2.4 Land Use and Land Cover in the Watershed

Conetoe Creek is a rural watershed containing only a few, small population centers. The only population centers within the study area are the Town of Conetoe, which has a population of 365; and a portion of the Town of Bethel, which has a population of 1681 (US Census, 2000).

Land cover for the study area is available from a statewide data base developed from 1993 LANDSTAT imagery for the North Carolina Center for Geographic Information System Analysis (Earth Satellite Corporation, 1997). See Appendix C for additional information on this data set. These data indicate that row crops (Exhibits 2.5 and 2.6) comprised 40% of the land cover in the study area in 1993, while a similar area was forested and less than one percent was developed (Table 2.2 and Figure 2.2). Land cover and land use are believed to have changed little over the past decade.

Table 2.2 Land Cover in the Conetoe Creek Study Area, 1993

Land Cover Category	%
Cultivated areas	40.4
Bottomland forest/hardwood swamp	15.9
Other forest	24.1
Shrubland	17.6
Developed areas	0.7
Managed herbaceous vegetation	1.2
Water	<0.1

Source: 1993 Landsat imagery. See Appendix C.



Exhibit 2.5 Cotton field in the Conetoe Creek watershed



Exhibit 2.6 Irrigated field under cultivation near Conetoe Creek

Cotton is the predominant crop in the study area, although soybeans, peanuts, corn, tobacco and sweet potatoes are also grown. Although information regarding the number of acres planted in each of these crops within the study area was not readily available, Edgecombe County NRCS staff have indicated that percentages in the study area closely approximate those found in Edgecombe County as a whole (Table 2.3).

Table 2.3 Edgecombe County Crop Acreage, 2002

Crop	Acres	% of Total Crop Acreage
Cotton	54,915	50.2
Soybeans	19,954	18.3
Peanuts	11,571	10.6
Corn	11,392	10.4
Tobacco	4,449	4.1
Sweet potatoes	3,947	3.6
Cucumbers	2,566	2.3
Other crops	496	0.5
Total Acreage under Cultivation	109,290	

Source: USDA NRCS, Edgecombe County.

2.5 Sources of Pollution

2.5.1 Historical Issues

European colonists first settled in the watershed in the early to mid-17th century. Although hunting and livestock served as the primary means of support during early settlement, a diverse agricultural economy was soon established including corn, soy, peas, oats, rice, wheat, sweet potatoes, cotton and flax. While cultivation of a variety of crops continued throughout the settlement era, tobacco became the most profitable crop for market. When good farm-to-market roads were established, the area became known as an outstanding agricultural region providing tobacco, peanuts, cotton, soybeans, corn and small grains (Goodwin, 1979).

Perhaps the most enduring impact of the watershed's agricultural history on stream integrity has been the drainage of the land and the channelization (straightening and dredging) of waterways. Subsurface tile drainage has been installed widely throughout eastern North Carolina to facilitate the dewatering of the land surface following rains. Channelization allows drainage to occur more rapidly and deeply, increasing the acreage suitable for agricultural production.

The first efforts to channelize Conetoe Creek were undertaken by European colonial settlers in the 1700s, and drainage projects continued over the next two centuries. The first large-scale channel modification efforts were sponsored by the Work Projects Administration (WPA) in the early 20th century. According to several long-term watershed residents, the WPA efforts

unearthed pipes produced in England during the 1730s and laid by early settlers. During the 1960s, the Soil Conservation Service (now the Natural Resource Conservation Service, NRCS) carried out a second and larger channel modification project under the federal Public Law 566 watershed improvement program. This project, completed in 1969, involved the dredging and straightening of the entire length of Conetoe Creek and its major tributaries. According to Heath (1971), the project involved 95 miles of channel and was jointly funded by state (\$840,000) and federal (\$667,000) sources.

Edgecombe County Drainage District #2 has a maintenance agreement with the NRCS to maintain Conetoe Creek's channels and drainage ditches. The agreement dates to completion of the last major channelization project in the 1960s. Easement maintenance is performed by a private firm through a contract with the drainage district. Maintenance activities include inspection, mowing of access roads, and removal of obstructions from the easement as well as inspection and limited clearing of the channel (Exhibit 2.7). Larger snagging projects are referred to the drainage district following inspection. The Drainage District is administered by a Board of Drainage Commissioners, elected by local property owners, with NRCS serving in an advisory capacity. These channel modification activities have increased the viability of agricultural activities in the watershed, but have had enduring negative impacts on aquatic habitat (see Sections 4 and 6).



Exhibit 2.7 Maintained drainage easement paralleling Conetoe Creek

2.5.2 Wastewater Discharges

The only NPDES discharge in the study area is the Town of Bethel's wastewater treatment plant (NC0061514), which is permitted to discharge up to 0.75 million gallons per day (MGD) into Conetoe Creek (Figure 2.1). Discharge is contingent on the presence of adequate flow (12.0 cfs May through October and 4.5 cfs November through April, as measured at the USGS gage downstream). The waste stream entering the plant is almost entirely domestic, as there are few industrial facilities in the service area.

Since 1992, the plant has been operating under a Special Order by Consent (SOC) from the North Carolina Environmental Management Commission (EMC SOC WQ 92-08). The SOC modified NPDES effluent concentration limits (Table 2.4) for ammonia nitrogen, total nitrogen, total phosphorus, and biochemical oxygen demand (BOD₅). The previous NPDES limits, with which the town had been unable to comply, were modified to allow the town enough time to plan and undertake construction of additional treatment works. Construction to link the WWTP to nearby Greenville's WWTP is currently in progress. Under the SOC, the Town of Bethel is required to discontinue wastewater discharges to Conetoe Creek by October 1, 2003.

Four permit violations occurred between January 2000 and June 2002. These include several instances of failure to meet monitoring requirements, one flow violation and a BOD₅ violation in March 2001, when the monthly BOD₅ average of 51.66 mg/L exceeded the 50.00 mg/L limit. The facility is not required to perform whole effluent toxicity tests. Total residual chlorine is monitored by the plant, but is not limited.

Table 2.4 Selected Effluent Limits, Bethel WWTP (NC0061514)

Parameter	Unit	NPDES Permit Limits		SOC Modified Limits	
		Monthly Average	Weekly Average	Monthly Average	Weekly Average
BOD ₅	mg/L	30.0	45.0	50.0	75.0
Ammonia Nitrogen	mg/L	2.0		4.0	
Total Nitrogen	mg/L	6.0		Monitor Only	
Total Phosphorus	mg/L	1.0		Monitor Only	

Monthly effluent self-monitoring data for 2001 and 2002 (Table 2.5) indicate that high levels of nutrients and BOD are often discharged to Conetoe Creek. BOD₅ concentrations above 30 mg/L are common, as are monthly average ammonia concentrations in excess of 1 mg/L.

Total residual chlorine concentrations over the period averaged 0.23 mg/L, with individual concentrations as high as 0.95 mg/L recorded.

Table 2.5 Selected Monthly Average Effluent Concentrations for Bethel WWTP (NC0061514), January 2001 – June 2002

Year and Month	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)	Ammonia (mg/L)	BOD ₅ (mg/L)	Fecal Coliform (# col/100ml)	Total Residual Chlorine (mg/L)
2001						
January	1.14	8.98	1.05	30	1.4	0.47
February			1.83	22.5	1	0.32
March			1.93	51.7	3.8	0.17
April			1.04	37	6.9	0.14
May			0.14	37	0	0.06
June			0.44	30.3	2.5	0.21
July			0.22	23	280	0.07
August			1.06	23	18.2	0.1
September			2.05	49	0	0.13
October			0.15	30	4.1	0.37
November	1.12	6.26	0.16	26	2.2	0.38
December						
2002						
January			1.8	43.3	13.8	0.34
February	1.43	9.17	1.9	38.7	1.6	0.29
March			0.45	40.5	44.7	0.22
April			0.24	32.5	174.9	0.11
May	0.86	8.99	0	39	1	0.31
June			0	31	1	0.3

* Source Bethel WWTP self-monitoring reports. Blank cells indicate no data are available.

2.5.3 Crop and Animal Agriculture

Since agriculture is the dominant land use in this sparsely populated watershed, agricultural activities must be considered as potentially important sources of pollutants. This section provides general background on agricultural pollution followed by a description of agricultural activities in the Conetoe Creek watershed.

Agricultural activities that may impact water quality include cultivation, irrigation, pesticides, chemical fertilizer and manure applications to fields and crops and confined animal feeding operations (CAFOs). The major pollutants associated with these activities are nutrients, pesticides, sediments and pathogens (NCDWQ, 2000). Potential impacts of agricultural activity are discussed by National Research Council (1993), Nolan et al. (1998), and USGS (1999a and 1999b).

The potential for agricultural impacts in this part of North Carolina is underscored by a number of recent studies and activities:

- As part of the National Water Quality Assessment Program (NAWQA), the USGS has studied various streams in the Albemarle-Pamlico drainage (Spruill et al., 1998), encompassing the Chowan, Roanoke, Tar-Pamlico and Neuse River basins. All of these basins were found to have excess nitrogen and phosphorus concentrations. The USGS cites agricultural fertilizer and livestock as the major sources of these excess nutrients, accounting for 50 percent of nitrogen and 75 percent of phosphorus originating in these basins.
- USGS stream studies also cite the Tar-Pamlico River basin as having the highest incidence of pesticide detection of any basin in the Albemarle-Pamlico drainage (Spruill et al., 1998). Stream sediment samples collected from the Tar-Pamlico basin between 1969 and 1990, showed levels of DDT (an organochlorine pesticide no longer in current use) and its break-down products at levels exceeding benchmark values for adverse biological effects (Spruill et al., 1998).
- DWQ's 1999 Tar-Pamlico River Basinwide Water Quality Plan (NCDWQ, 1999) cites Conetoe Creek at SR 1402 as having the highest nitrite/nitrate levels of any ambient station in the Tar-Pamlico River Basin. The plan also notes that intermittent high phosphorus levels suggest a possible runoff or discharge problem.
- In 1996, the State of North Carolina conducted a program to test wells adjacent to swine farms for elevated nitrate levels. Edgecombe County, where elevated nitrate levels were found in 34.7% of 75 wells sampled, was among the five counties showing the highest concentrations in the study (Okun, 1999).

Confined animal operations. The study area contains seven permitted swine operations (Table 2.6 and Figure 2.3). Two of these farms are not currently operative. Clover M Farms is located in the floodplain and is participating in the state buyout program. Weathersby & Son, which is for sale, has been depopulated for five years (although lagoons are still present on site). These are the only operations in the study with unlined lagoons (unlined lagoons can be associated with higher rates of infiltration to ground and nearby surface waters). The five active operations are classified as either "farrow to wean" or "feeder to finish". Farrow to wean refers to the period from birth to weaning, while feeder to finish refers to the period between weaning and slaughter. All of the permitted facilities in the study area were in compliance with applicable regulations during the period of this study, except for a records violation at one site. In 1994, the number of swine in the study area increased from approximately 2,200 to 21,200, when several new operations opened. Swine populations increased to 26,200 in 1995. Several small poultry operations are also in the watershed.

Table 2.6 Permitted Animal Operations in the Conetoe Creek Study Area

Facility Name	Facility Number	Facility Type and Number of Animals	Lagoon Capacity (Cubic feet)	Nearest Waterway
SMS Multiplier	33-6	1200 farrow to feeder 4000 feeder to finish	2,957,970	Conetoe Creek
Blount Bros. Farm	33-20	2150 farrow to ween	1,435,434	Crisp Creek
Creekside Farms	33-7	5000 farrow to ween	4,291,557	Fountain Fork Creek
Clover M Farms, Inc.- Conetoe Farm*	33-52	400 farrow to ween	174,618	Conetoe Creek
Ronald Crawford Farm	74-120	1920 feeder to finish	578,867.7	Conetoe Creek
Weathersby & Son**	33-25	720 feeder to finish 1038 wean to feeder	196,929	Fountain Fork Creek
George Crawford Farm	33-63	4800 feeder to finish	1,438,731	Fountain Fork Creek

* No longer in operation. Part of state floodplain buy-out program. Unlined lagoon.

** Farm for sale. Currently not in operation. Unlined lagoon.

Source: DWQ Non-Discharge Permitting Unit.

Row crops. As discussed earlier, row crops cover 40% of the watershed, with cotton accounting for about half of the cultivated acreage. Fertilizer application rates for the major watershed crops are listed in Table 2.7.

Table 2.7 Typical Nitrogen and Phosphorus Application Rates for Major Crops Grown in the Conetoe Creek Watershed

Crop	Nitrogen (lbs/acre)	Phosphorus (lbs/acre)
Cotton	80	25
Soybeans	<5*	20
Peanuts	0	0
Corn	140	35
Tobacco	80	40

Source: North Carolina Cooperative Extension Service Edgecombe County Center, 2002.

Crops listed in order of descending acreage.

* Nitrogen applied to soybeans is a byproduct of blended fertilizer used on some acreage.

A wide range of pesticides is used on these crops, including various herbicides, insecticides, growth regulators and defoliant. Cotton is associated with diverse chemical usage. Typical pesticides used in the study area are listed in Table 2.8. A variety of application methods are used, depending on the pesticide and the particular situation, including soil application or injection and aerial spraying. Spraying from a ground rig is the method most commonly used.

Erosion of soil from fields and delivery of sediment to Conetoe Creek was periodically observed during the study (Exhibit 2.8).



Exhibit 2.8 Sediment in agricultural ditch along SR 1510 on its way from field to stream

Table 2.8 Common Pesticides Used on Major Crops, Conetoe Creek Watershed

Crop	Pesticide	Use	Application Method	Time of Application
Cotton	pendimethalin	Herbicide	Soil application	May
	paraquat	Herbicide	Ground rig	March
	2,4-D	Herbicide	Ground rig	February
	carfentrazone	Herbicide	Ground rig	June, October
	aldicarb	Insecticide	Soil application	May
	fluometuron	Herbicide	Soil application	May
	glyphosate	Herbicide	Ground rig	Late May-late June
			Burn down	March
	prometryn	Herbicide	Applied to plant base	June
	mepiquat chloride	Growth regulator	Ground rig	Early June-late August
	synthetic pyrethroids	Insecticide	Aerial or ground rig	Late July-early August
	acephate	Insecticide	Aerial or ground rig	May
	tribufos	Herbicide, defoliant	Aerial or ground rig	September-October
	ethephon	Growth regulator, Defoliant	Aerial or ground rig	Early October
Soybeans	pendimethalin	Herbicide	Ground rig	May
	glyphosate	Herbicide	Ground rig	May
	thiodicarb	Insecticide	Aerial or ground rig	August
Peanuts	metolachlor	Herbicide	Ground rig	May
	metam sodium	Fumigant	Soil application	April
	propiconazole	Fungicide	Ground rig	July-September
	azoxystrobin	Fungicide	Ground rig	July-September
	paraquat	Herbicide	Ground rig	May
	bentazon and acifluorfen mix	Herbicide	Ground rig	May
	imazapic	Herbicide	Ground rig	May
	tebuconazole	Fungicide	Foliar	July-September
	chlorothalonil	Fungicide	Foliar (aerial, ground)	July-September
Corn	paraquat	Herbicide	Ground rig	April
	glyphosate	Herbicide	Ground rig	March
	2,4-D	Herbicide	Ground rig	June
	atrazine	Herbicide	Ground rig	April
	metolachlor	Herbicide	Ground rig	April
	ametryn	Herbicide	Applied to plant base	June
Tobacco	fenamiphos	Nematicide	Soil application	April
	chlorpyrifos	Insecticide	Soil application	April
	dimethomorph & mancozeb	Fungicide	Ground rig	June
	spinosad	Insecticide	Ground rig	June
	ethephon	Growth regulator	Ground rig	September
	acephate	Insecticide	Ground rig	May-September
	imidacloprid	Systemic insecticide	Greenhouse application	April
	flumetralin	Growth Regulator	Ground rig	June-July
	maleic hydrazide	Growth Regulator	Ground rig	June-July
Sweet potatoes	endosulfan	Insecticide	Ground or aerial	July-September
	1,3-dichloropropene	Fumigant	Soil application	April
	phosmet	Insecticide	Soil application	May-August
	chlorpyrifos	Insecticide	Soil application or broadcast	May
	clomazone	Herbicide	Soil application	Early May

Source: North Carolina Cooperative Extension Service Edgecombe County Center, 2002.

Agricultural Best Management Practices (BMPs). Edgecombe County NRCS staff indicate that water control structures and conservation tillage are widely used in the study watershed. Water control structures (risers) are used extensively to control water levels in ditches and on laterals. Conservation tillage, which requires that a minimum of 30% of residue crop cover remain following planting, is used on approximately 80% of cropland (strip-till accounts for 70% and no-till accounts for 10%). Other BMPs used include field borders (15 to 20-foot wide grassy borders along ditches and laterals), which are used on approximately 10% of cropland.

According to Edgecombe County NRCS staff, the majority of farmers in the watershed practice some form of integrated pest management, including field inspections to target insecticides to particular pests. Soil testing is commonly conducted to determine appropriate fertilizer application rates.

2.5.4 Other Sources

Runoff from the towns of Conetoe and Bethel likely has a minimal impact on Conetoe Creek at present. Both towns have very limited populations in the study area, which includes very little commercial activity. Other potential pollutant sources are discussed below.

Septic systems. Most of Bethel is served by the town's sanitary sewer system. The Conetoe area and rural residences are served by septic systems. The condition of these systems is unknown, but based on the relatively low population density it seems unlikely that septic systems are a major source of pollutants.

Greenleaf Nursery. The Greenleaf Nursery is a wholesale nursery raising ornamental trees and shrubs. The nursery is located near the intersection of Manning and Chinquapin Road, adjacent to Ballahack Canal. The nursery currently occupies 290 acres, but is expected to expand to 600 acres in the future. Irrigation occurs via a recirculation system which pumps water from a holding pond to graded beds (Exhibit 2.9). The beds drain to plastic lined ditches that return irrigation to holding ponds. Floodwaters are prevented from entering ponds by a dyke that extends around the side of the nursery adjacent to Ballahack Canal.

Dumping. Observations during the study indicate that streams in the study areas are commonly used to dispose of unwanted materials. Staff have frequently seen deer carcasses in streams, especially during hunting season, that appear to have been thrown from bridges. Other animal components, including goat carcasses and swine parts, were also observed in streams. These carcasses have the potential to introduce pathogens and additional organic material to streams. Empty pesticide containers, which require careful handling and disposal, were also commonly found along roadways and occasionally in streams.



Exhibit 2.9 Greenleaf Nursery

2.6 Trends in Land Use and Development

According to Edgecombe County NRCS staff, although crop acreage in the county has remained fairly stable, the number of individuals farming this acreage has decreased from 600 in 1987 to 125 in 2001. Although exact figures for the study area were not available, Edgecombe County NRCS staff confirm that this trend applies there as well.

Currently, six individuals farm the majority of acres in the study area. All of these individuals lease at least a portion of the land they farm. Leases, which typically run for one year, have been cited as a major impediment to the adoption of conservation farming practices.

Cooperative Extension agency staff familiar with the watershed report that although the acreage under cultivation in the study area has remained stable over the past ten years, the acreage planted in each crop has changed. Although precise figures are not available, tobacco cultivation has declined by an estimated 30 to 40%, while cotton acreage has increased substantially. Slight decreases in corn and soybean cultivation have occurred.

Unlike many North Carolina counties, population in Edgecombe County is exhibiting a slight downward trend. The Edgecombe County population decreased 1.9% between 1990 and 2000 and is projected to decrease 2.9% between 2000 and 2010 and 3.5% between 2010 and 2020 (US Census Bureau, 2002).

2.7 Regulatory Issues and Local Water Quality Activities

Tar-Pamlico River Basin Nutrient Rules. Eutrophication has been a concern in the Pamlico estuary for many years, and a nutrient sensitive waters strategy was first implemented in 1989. In 2000, the NC Environmental Management Commission approved a series of rules to reduce nutrient inputs of nitrogen and phosphorus to the Pamlico estuary. The intent of these rules, modeled after those enacted in the adjacent Neuse River Basin in 1998, was to reduce nutrient inputs into the Pamlico estuary. The package of regulations includes rules on riparian buffers, nutrient management, stormwater management and agriculture.

Agriculture Rule. The agriculture rule is designed to achieve:

1. A 30% reduction in nitrogen loading from 1991 baseline levels within 5 to 8 years of the rule's effective date (September 1, 2001).
2. Control of phosphorus at or below 1991 levels within 4 years of approval of a phosphorus accounting method called for in the rule.

Implementation will be achieved through a cooperative effort between a Basin Oversight Committee (BOC) and, in each county or watershed, a Local Advisory Committee (LAC). Farmers who are involved in commercial production of crops or horticultural products, or whose livestock or poultry exceed a specified number, are subject to the rule and required to register with their LAC during the first year the rule is in effect, or by September 1, 2000. Not all farmers are required to implement specific practices in the first five years, but each LAC is required to achieve its overall nutrient goal through the implementation of BMPs by agricultural operations in its area.

Buffer Protection Rule. The buffer protection rule requires that existing riparian vegetation be maintained on both sides of intermittent and perennial streams. This rule does not establish new buffers unless the existing use in the buffer area changes. The footprints of existing uses (such as cropland, buildings and maintained lawns) are exempt. Where applicable, the rule requires 50 feet of buffer on each side of the stream, the inner 30 feet of which must remain largely undisturbed. Although this rule will impact new and changing land uses, its impact on current land uses in the study watershed is limited because: 1) the establishment of new buffers is only required if there is a change in the existing use of the buffer area; and 2) exemptions include maintenance of ditches and modified natural streams. Farmers can use the establishment of new buffers as part of their overall BMP strategy.

Nutrient Management Rule. The nutrient management rule requires people who apply fertilizer in the basin, except residential landowners who apply fertilizer to their own property, to either take state-sponsored nutrient management training or have a nutrient management plan in place for the lands to which they apply fertilizer. Applicators must comply with the rule by April 1, 2006.

Stormwater Rule. This rule requires six municipalities and five counties, including Edgecombe and Pitt Counties, to develop and implement stormwater rules within two and a half years. Local programs must include:

- The permitting of new development to keep phosphorus from exceeding predevelopment levels and to reduce nitrogen runoff by 30% (compared to pre-development levels).
- Efforts towards treating runoff from existing developed areas.
- The identification and removal of illicit discharges.
- Education for developers, businesses and homeowners.

Citizen Initiatives. The Pamlico-Tar River Foundation (PTRF) is an educational nonprofit organization of approximately 2000 members. The PTRF works to protect water quality, wetlands and other critical habitat for fisheries, wildlife and waterfowl in the Tar-Pamlico River Basin, although it has not focused specifically on the Conetoe Creek watershed. Examples of issues in which PTRF has been involved include municipal wastewater treatment, development plans, wetland loss, nutrient enrichment and fisheries regulation.

Section 3

Potential Causes of Biological Impairment

The study identified those factors that were plausible causes of biological impairment in the Conetoe Creek watershed using both biological assessment and watershed-based approaches. An evaluation of benthic community data and other biological and habitat indicators can point toward general types of impacts that may likely impact aquatic biota. These stressors were flagged for further investigation. Land uses and activities in the Conetoe Creek watershed were also examined to identify potential stressors for evaluation.

3.1 Key Stressors to be Evaluated in the Conetoe Creek Watershed

The following were evaluated as the most plausible candidate causes of impairment in Conetoe Creek.

1. Habitat Degradation. Habitat degradation was evaluated as a potential cause of biological impairment based on the long history of channel modification and an initial review of available habitat assessments, which indicated a lack of organic habitat such as logs and snags, as well as extensive bank erosion. These characteristics create an inhospitable environment for aquatic invertebrates and fish, even if water quality factors are favorable.

2. Organic and Nutrient Enrichment/Low Dissolved Oxygen. Organic enrichment can affect stream biota in several ways. Organic matter in the form of leaves, sticks and other materials provides a food source for aquatic microbes and serves as the base of the food web for many small streams. When microbes feed on organic matter, they consume oxygen in the process and make nutrients available to primary producers, especially periphyton. Macroinvertebrates feed on the microbial community and are, in turn, consumed by fish.

These processes are natural and essential to the health of small streams. However, excessive amounts of organic matter (oxygen-consuming wastes and nutrients) from human or animal waste can increase the microbial activity to levels that significantly reduce the amount of oxygen in a stream. Excessive inorganic nutrient inputs can also impact stream biology. Adequate dissolved oxygen is essential to aquatic communities; only certain aquatic invertebrates are able to tolerate low oxygen levels. These excessive organic materials also serve as food for certain aquatic invertebrate groups that can dominate the invertebrate community. Excess organic and nutrient loading can thus result in a distinct change in community composition due to both a change in food source and low dissolved oxygen levels.

An initial review of DWQ benthic macroinvertebrate data from the Conetoe Creek study area revealed that benthic community assemblages were indicative of low DO conditions. Primary watershed land uses (including extensive row crop production and swine operations) as well as the presence of a municipal wastewater discharge, also suggest the potential for enrichment.

3. *Toxic Impacts.* Water quality monitoring conducted by the USGS in agricultural areas of the Tar-Pamlico River basin indicated the presence of numerous pesticides in surface waters (see Section 2). Given the intensive row crop activity within the Conetoe Creek watershed, pesticide impacts merit additional investigation. Initial review of DWQ benthic macroinvertebrate sampling data for Conetoe indicated community assemblages indicative of toxic impacts.

Section 4

Biological Conditions and Stream Habitat

Biological assessment (bioassessment) involves the collection of stream organisms and the evaluation of community diversity and composition to assess water quality and ecological conditions. Evaluation of habitat conditions at sampling locations is an important component of bioassessment.

Prior to this study DWQ's Biological Assessment Unit (BAU) collected macroinvertebrate samples from Conetoe Creek at the USGS gage station at SR 1409 on eight occasions. Most samples collected in 1985, 1986, 1988, 1989 and 1992 were rated as Fair (some individual samples in 1988 and 1989 were rated Good-Fair). The sample collected in 1997 was rated Poor. DWQ has not collected fish community data in the Conetoe Creek watershed.

Additional benthic community sampling was conducted during the present study to serve several purposes:

- To account for any changes in biological condition since the watershed was last sampled in 1997.
- To obtain more specific information on the actual spatial extent of impairment.
- To better differentiate between portions of the watershed contributing to biological impairment and those in good ecological condition.
- To collect additional information to support identification of likely stressors affecting the benthic community.

This section describes the approach to bioassessment used during the study and summarizes the results of this work. Additional photographs of the sampling sites and a more detailed analysis of the condition of aquatic macroinvertebrate communities in the Conetoe Creek watershed may be found in Appendix A.

4.1 Approach to Biological and Habitat Assessment

Biologists surveyed macroinvertebrate communities and aquatic habitat at five locations on the mainstem of Conetoe Creek, two locations on tributary streams and two locations on reference streams outside of the study area (Figure 4.1). Sites are described in Section 4.2. The reference streams do not represent undisturbed conditions, but serve as comparison sites within the same ecoregion as Conetoe Creek.

4.1.1 Benthic Community Sampling and Rating Methods

Macroinvertebrate sampling was carried out using the general procedures outlined in the Division's standard operating procedures (NCDWQ, 2001b). Reaches approximately 100 meters (328 feet) long were targeted, although the actual stream length sampled varied with site conditions. Historically, standard qualitative sampling (full scale method) was used for sampling at SR 1409. This method included ten samples: two kick-net samples, three bank sweeps, two

rock or log washes, one sand sample, one leaf pack sample, and visual collections from large rocks and logs. In the present study, this method was initially used at most sites, while at smaller stream sites the abbreviated Qual 4 method was used. The Qual 4, which has been used by DWQ to sample small streams for some time, involved four samples: one kick, one sweep, one leaf pack and visual collections. Organisms were identified to genus and/or species.

As the study progressed, however, the lack of adequate streamflow outside of the winter months indicated that the swamp sampling protocol was probably more appropriate than the standard qualitative or Qual 4 methods. Consequently, the swamp sampling method (involving nine sweeps, three rock/log washes and visual collections) was used for samples collected in 2002.

Two primary indicators or metrics are derived from macroinvertebrate community data: the diversity of a more sensitive subset of the invertebrate fauna is evaluated using EPT taxa richness counts; and the pollution tolerance of those organisms present is evaluated using a biotic index (BI). "EPT" is an abbreviation for Ephemeroptera + Plecoptera + Trichoptera (mayflies, stoneflies and caddisflies), insect groups that are generally intolerant of many kinds of pollution. Generally, the higher the EPT number, the more healthy the benthic community. A low biotic index value indicates a community dominated by taxa that are relatively sensitive to pollution and other disturbances (intolerant). Thus, the lower the BI number, the more healthy the benthic community.

Where the standard qualitative or Qual 4 sampling methods are used, biotic index values are generally combined with EPT taxa richness ratings to produce a final bioclassification (Excellent, Good, Good-Fair, Fair or Poor). Final bioclassifications are used to determine if a stream is impaired. Streams with bioclassifications of Excellent, Good and Good-Fair are all considered to be fully supporting their uses (are not unimpaired). Those with Fair and Poor ratings are considered impaired. *Under current DWQ policy, streams fewer than four meters in width are generally not formally rated but are evaluated qualitatively based on professional judgment.* Small streams sampled using the Qual 4 method that have scores consistent with a Good-Fair or better rating are labeled as 'not impaired'. Since rating criteria have not been finalized for the swamp sampling method, ratings could not be given to samples for which that method was employed. Because much of the Conetoe Creek channel system was observed to exhibit swamp-like qualities during much of the study period, samples collected by standard qualitative and Qual 4 methods are considered as swamp samples and are reported as Not Rated.

4.1.2 Midge Deformity Analysis

The use of *Chironomus mentum* (mouth structure) deformities is a good tool for toxicity screening (Lenat, 1993). At least 20-25 *Chironomus* are evaluated for deformities and a "toxic score" is computed for each site. DWQ data have shown the percent deformities for sites rated Excellent, Good and Good-Fair averaged about 5%, with a mean toxic score of about 7. Sites with Fair and Poor bioclassifications with stressors considered nontoxic were combined into a polluted/nontoxic group, with a deformity rate of 12% and a mean toxic score of 18. "Nontoxic" conditions for this group includes solely organic discharges (animal wastes) and natural organic loading (swamps). Finally, sites affected by a toxic stressor had higher deformity rates. A Fair/Toxic group had a 25% deformity rate and a mean toxic score of 52. A further significant increase was seen for the Poor/Toxic group: mean deformity rate = 45%, mean toxic score =

100. In Conetoe Creek, sufficient numbers of *Chironomus* for the deformity analysis were collected only at the US 64 Business location.

4.1.3 *Habitat Assessment Methods*

At the time benthic community sampling was carried out, stream habitat and riparian area conditions were evaluated for each reach using DWQ's standard habitat assessment protocol for coastal plain streams (NCDWQ, 2001b). This protocol rates the aquatic habitat of the sampled reach by adding the scores of a suite of local (reach scale) habitat factors relevant to fish and/or macroinvertebrates. Total scores range from zero (worst) to 100 (best). Individual factors include (maximum factor score in parenthesis):

- channel modification (15);
- in-stream habitat variety and area available for colonization (20);
- bottom substrate type and embeddedness (15);
- pool variety and frequency (10);
- bank stability and vegetation (20);
- light penetration/canopy coverage (10); and
- riparian zone width and integrity (10).

4.2 Findings

4.2.1 *Description*

Selected habitat and biological characteristics for each site sampled during the study are shown in Table 4.1. Some streams were too small to be given a formal rating (bioclassification). A narrative summary of conditions at each current site follows. See Appendix A for additional details.

Conetoe Creek Mainstem:

Conetoe Creek at SR 1516. This is the most upstream site on the mainstem of Conetoe Creek and was selected in an attempt to identify a site subject to fewer stressors than more downstream locations. This site had an intact riparian zone on one side and poor habitat. This highly impacted site showed extremely low EPT richness and abundance and the second lowest total taxa richness in the watershed. The few organisms present were generally tolerant benthos, low DO indicators and low flow/intermittent stream indicators. Benthic community composition at this site and the SR 1510 site indicated regular interruption of flow in the upper portions of the watershed.

Table 4.1 Selected Benthic Community and Habitat Characteristics, Conetoe Creek Study Sites

Location	Date	Method ¹	Stream Width (m) ²	Substrate %: silt-sand-coarse ³	Habitat Score (max. of 100) ⁴	EPT ⁵ Taxa Richness	EPT Abundance ⁶	Biotic Index ⁵	Midge Deformity Score ⁵	Bioclassification ⁵
Conetoe Ck. at SR 1409	7/23/85	FS	6	10-90-0		7	40	6.27		Fair
	7/12/88	FS	7	0-90-10		8	62	6.55		Good-Fair
	7/11/89	FS	9	0-100-0		8	59	6.66		Good-Fair
	10/25/89	FS	9	0-100-0		13	46	6.93		Fair
	7/20/92	FS	7	5-85-10		7	29	6.78		Fair
	8/19/97	FS	7	5-85-10		4	6	7.66		Poor
	11/2/00	FS	9	35-65-0	50	4	15	7.34		Not Rated*
Conetoe Ck. at US 64 Alt.	2/6/01	FS	5	15-60-25	49	5	25	7.2	100 (Toxic-Poor)	Not Rated*
Conetoe Ck. at NC 42	2/22/02	Sw	8	10-90-0	54	1	1	7.15		Not Rated*
Conetoe Ck. at SR 1510	11/2/00	FS	3	30-50-20	59	2	13	7.48		Not Rated*
	2/22/02	Sw	6	10-90-0	59	2	13	7.46		Not Rated*
Conetoe Ck. at SR 1516	2/6/01	Q4	2	15-85-0	53	2	2	7.12		Not Rated*
Ballahack Canal at NC 42	2/22/02	Sw	6	30-70-0	25	2	4	8.28		Not Rated*
Crisp Ck. at SR 1527	2/7/01	FS	5	20-80-0	45	4	6	7.35		Not Rated*
	2/11/02	Sw	7	30-55-0	44	2	11	7.7		Not Rated*
Sasnet Mill Br. at SR 1222	2/7/01	Q4	2	5-95-0	64	5	43	6.27		Not Rated*
Whichard Br. at SR 1521	2/8/01	FS	4.5	10-85-5	70	7	22	6.86		Not Rated*
	2/12/02	Sw	5	10-90-0	63	6	24	7		Not Rated*

1. FS = full scale (standard qualitative); Sw = swamp; Q4 = Qual 4; see text for discussion.

2. Wetted channel width at time of sampling.

3. Based on visual estimate of substrate size distribution; coarse denotes substrate larger than sand.

4. Habitat data available for 2000-2002 samples only; see text for list of component factors.

5. See text for description.

6. Number of individual EPT organisms collected.

* Samples not rated due to use presence of swamp-like summer flow conditions; see text for discussion.

Conetoe Creek at SR 1510. This site provides a second location in the upper watershed, located just upstream of the confluence with Fountain Fork Creek (Exhibit 4.1). Land use in this portion of the watershed is mostly active cropland, but also includes forest and residential areas. Banks are steep and moderately eroded, but are vegetated with hardwoods. Sticks and leaf packs provide in-stream habitat. Benthos considered tolerant of organic enrichment, low DO and low-flow conditions were common and toxicity indicators were present.

Conetoe Creek at NC 42. This is the most downstream mainstem sampling site in the upper watershed, located upstream of the confluence with Crisp Creek (Exhibit 4.2). Root mats and undercut banks provided some habitat, though overall habitat was poor as at other Conetoe Creek locations. EPT richness and abundance were the lowest in the watershed; only a single EPT taxon was found. Taxa tolerant of a variety of stressors were common, with enrichment, low DO and toxic indicators present.

Conetoe Creek at US 64 Alt. (Business). This site is approximately 1.25 miles downstream of the Bethel WWTP discharge, at the railroad trestle below the US 64 bridge. Surrounding land use includes active cropland and fallow fields. Because the sampling reach included the trestle area, the bottom substrate included gravel, rubble and boulders from trestle construction and stabilization, and riffles were present. Perhaps because of the riffle habitat, this site had the greatest EPT abundance (25) and richness (5) in the Conetoe Creek system, though this still represented highly degraded conditions. The community was generally tolerant of organic enrichment, low-flow low DO and toxicity. *Chironomus* were sufficiently abundant to conduct a midge deformity analyses. A score of 100 indicated Toxic-Poor conditions.

Conetoe Creek near SR 1409. Historically sampling took place at the SR 1409 bridge near the USGS stream gage. This location was inaccessible during the present study due to backwaters from a dam downstream of the gage, so the sampling location was moved about one and one half miles upstream, downstream of the confluence with Ballahack Canal. Adjacent land use was primarily active cropland but included forested and residential areas. In-stream habitat was sparse. Stream banks were unstable, perhaps the result of recent snagging activities. Benthic diversity was extremely limited here and the BI was high, similar to other locations on the Conetoe Creek mainstem. Midges were conspicuously lacking.

Tributaries:

Crisp Creek at SR 1527. This site is the most downstream location that is accessible on this major tributary. Land use adjacent to this catchment included active cropland, fallow fields and a small amount of forest. Bottom substrate is sand and silt, and sticks and leaf packs were common though in-stream habitat was otherwise limited (Exhibit 4.3).

Taxa richness and EPT richness were comparable to other sites in the watershed, although EPT abundance was particularly low in February 2001. Benthic community composition suggests this is a heavily impacted stream with indications of low DO conditions, organic enrichment and toxicity.

Ballahack Canal at NC 42. This station is located near the downstream end of Ballahack Canal, in the small Town of Conetoe (Exhibit 4.4). The riparian area is in extremely poor condition and had limited woody vegetation. Filamentous algae were abundant. The site exhibited the poorest

habitat, the lowest overall taxa richness (see Appendix A), and the highest BI in the study area. Even many tolerant species were lacking at this site, suggesting toxic impacts.

Potential Reference Streams:

Sasnet Mill Branch at SR 1222. Sasnet Mill Branch is located in Edgecombe County, southwest of Tarboro (see map in Appendix A). This site was chosen as a potential comparison stream because, unlike streams in the study area, the immediate vicinity of the site has substantial forest cover and the watershed, though agricultural, appeared to have less intensive activity than Conetoe Creek. The bottom substrate was primarily sand, though traces of gravel and silt were present. In-stream habitat was comprised of detritus and root mats. Overall habitat was somewhat better than at any of the sites sampled in the study area.

This stream was clearly degraded, although both EPT richness and the BI were somewhat better than any of the Conetoe Creek sites. EPT richness was low and EPT taxa present in relative abundance were tolerant. Only one stonefly taxon was present, although stoneflies were absent entirely in most of the Conetoe Creek drainage. A few low flow indicator species were observed.

Whichard Branch at SR 1521. This stream is located in Pitt County, southeast of Bethel (see map in Appendix A). This site was chosen because, although it is surrounded by active cropland, it is also adjacent to a substantial forested area. Unlike streams in the study watershed, bends in Whichard Branch are natural and frequent, and pools are frequent and a variety of sizes. The bottom substrate was mostly sand, though traces of clay conglomerate and gravel are present. In-stream habitat included detritus and root mats, and overall habitat scores were better than in the Conetoe Creek watershed. This stream had the greatest EPT richness of all sites sampled, a relatively high EPT abundance, and a BI value lower than any Conetoe Creek site. These metrics still indicated a degraded stream, however. EPT taxa present were generally tolerant, indicators of low DO, low flow, organic enrichment and toxic impacts.

4.2.2 Summary of Conditions and Nature of Impairment

Habitat throughout the study area was poor. While a lack of riffles and a predominately sandy substrate are expected in coastal plain streams, the various organic in-stream habitats critical to macroinvertebrates in this part of North Carolina were largely missing. Sticks and leaf packs were relatively common at most locations, but other habitat types such as snags and root mats were rare. Channel complexity is completely lacking in this uniform channel system. The impacts of channelization and snagging activities are evident.

Conetoe Creek had previously been sampled only near the USGS gage at SR 1409. Data collected during the present study, however, indicated that benthic macroinvertebrate communities were extremely impacted at all sites sampled throughout the study area. While formal ratings were not assigned due to the use of swamp sampling protocols (for which rating procedures have not been finalized) or the presence of comparable summer flow conditions, substantial and widespread impacts to the benthic community were evident and it remains appropriate to consider Conetoe Creek impaired. Indicators of multiple stresses are widespread.

Fauna were very sparse, making determination of specific processes impacting the system difficult. Stoneflies were present at only one location, and four of the seven sites sampled in the watershed had two or fewer EPT taxa. Some locations were lacking midges and other tolerant taxa as well. These findings suggest substantial toxic and habitat impacts. Those indicator assemblages that were present point to widespread impacts from nutrient enrichment and low dissolved oxygen. Low flow indicators were particularly notable in the upper portion of the watershed (at and above SR 1510). Indicator taxa also point toward toxicity, as does a rating of Toxic-Poor at the US 64 Business site, the only location at which a midge deformity analysis could be conducted.

Streams sampled as potential comparison sites to Conetoe Creek, while exhibiting somewhat better habitat than Conetoe Creek and a slightly more diverse benthic community, were still degraded and do not represent even an approximation of reference conditions. Lower than average stream discharge during the period of study due to the ongoing precipitation deficit probably served to exacerbate low flow/nutrient enrichment impacts.



Exhibit 4.1 Conetoe Creek at SR 1510



Exhibit 4.2 Conetoe Creek at NC 42



Exhibit 4.3 Crisp Creek at SR 1527



Exhibit 4.4 Ballahack Canal at NC 42

Section 5

Chemical and Toxicological Conditions

Water quality assessment provides information to evaluate whether chemical and physical conditions negatively affect benthic communities. Two broad purposes of this monitoring are:

1. To characterize water quality conditions in the watershed.
2. To collect a range of chemical, physical and toxicity data to help evaluate the specific causes of impairment and to identify sources.

This section summarizes the data collection methods and discusses key monitoring results. See Appendix B for additional discussion of methodology and results. The DWQ conducts monthly sampling on Conetoe Creek at SR 1409 (ambient station number O6205000).

5.1 Methods

5.1.1 General Methodology

Watershed Water Quality Characterization. An overall picture of the physical and chemical conditions in the Conetoe Creek watershed was obtained by assessing water quality at an integrator station (Conetoe Creek at SR 1409). An integrator station is the monitoring station located the furthest downstream, providing an indication of upstream pollutant loading as well as the water quality leaving the study area. This site was monitored regularly for field parameters, nutrients and potential toxicants. Sampling at sites upstream of the integrator station provides information on pollutant sources.

Water samples were collected and field parameters were measured at baseflow and stormflow. Baseflow is defined as a period in which no measurable rain fell in the watershed during the 48 hours preceding sampling. Baseflow samples provide an indication of water conditions to which organisms may potentially be exposed for an extended period. Storms, however, bring a large influx of runoff that may carry potential toxicants or nutrients. Storm samples were typically collected during the rising stage of the hydrograph, while water levels were still increasing.

Eight baseflow and two storm samples were collected between May 2001 and August 2002 at the integrator station. Grab samples (static samples) were collected during both conditions.

Stressor and Source Evaluation. Samples were collected at a variety of locations to identify the major chemical and physical stressors to which the aquatic biota are exposed, evaluate toxicity, and assess major pollution sources. Station locations for stressor identification were linked to areas of known biological impairment (benthic macroinvertebrate sampling stations) and to watershed activities believed to represent potential sources of impairment.

Since much of the land use in the Conetoe Creek watershed is agricultural, sampling emphasized pollutants potentially associated with agricultural operations. Parameters included:

- metals;
- organochlorine pesticides and polychlorinated biphenyls (PCBs; EPA Method 608);
- selected current use pesticides (GC/MS-gas chromatography/mass spectroscopy); and
- nutrients.

Laboratory toxicity bioassays provide a method of assessing the presence of toxicity from either single or multiple pollutants and can be useful for assessing the cumulative effect of multiple chemical stressors. Acute toxicity tests were conducted on water samples collected during storms, while chronic tests were conducted on baseflow samples. The water flea, *Ceriodaphnia dubia*, was the indicator organism used for both the acute tests, which last for 48 hours and measure mortality, and the chronic tests, which last for seven days and examine reproductive rates. Acute toxicity tests used the protocols described in the USEPA document UPA/600/4-90/027F (USEPA, 1993). Chronic toxicity tests used the North Carolina *Ceriodaphnia* Chronic Effluent Toxicity Procedure (North Carolina Division of Water Quality, 1998).

Physical parameters (pH, dissolved oxygen, specific conductance standardized to 25° C and temperature) were measured in the field on numerous occasions throughout the watershed. Additionally, multiparameter probes with a data logging capacity (data sondes) were deployed on four dates for three to seven-day periods. Data sondes were simultaneously deployed at one to six sites on each date and were programmed to record the above parameters at 15-minute intervals.

Extended in-stream monitoring to evaluate long-term exposure to pollutants was conducted using semi-permeable membrane devices (SPMDs). These are passive sampling devices that accumulate hydrophobic organic pollutants to which the devices are exposed during deployment (see Appendix B for additional details). SPMDs were deployed four times, typically at two locations, for seven to eleven days.

Bed sediment was collected at one location and analyzed for metals, pesticides, polychlorinated biphenyls, polycyclic aromatic hydrocarbons, and organics. Chronic toxicity bioassay testing was conducted on sediment to evaluate potential toxicity. A forty-two day test was performed using *Hyallela azteca*, as described in ASTM (2000) and USEPA (2000b).

Water and Sediment Benchmarks. To evaluate whether observed concentrations may have a negative impact on aquatic life, measured concentrations were compared to EPA's National Ambient Water Quality Criteria (NAWQC) for freshwater (USEPA, 1999) and Tier II benchmarks (USEPA, 1995). Metals benchmarks were adjusted for hardness where appropriate (USEPA, 1999). For chromium, the NAWQC for Cr VI was used. The use of NAWQC and other benchmarks is discussed in more detail in Appendix B.

Sediment data were compared to sediment benchmarks used by the DWQ Aquatic Toxicology Unit (See Appendix B). They were grouped into conservative and non-conservative ranges in the manner of MacDonald *et al.* (2000). Conservative ranges ('no or low effects' benchmarks) are threshold values, below which there is low probability of toxicity. Region 4 USEPA values are included in the conservative values, but they are also presented separately because the DWQ Aquatic Toxicology Unit uses these as initial screening benchmarks. Non-conservative ranges ('probable effects' benchmarks) are values above which there is a high probability of toxicity. If a measured value falls between the low value of the conservative range and the high value of the

non-conservative range, it is possible that it is toxic, with higher concentrations indicating an increased probability of toxicity.

Benchmarks were used for initial screening of potential impacts. Final evaluation of the potential for pollutants to negatively impact aquatic biota considered all evidence, including toxicity bioassays, benthic macroinvertebrate data and data on analyte concentrations.

5.1.2 Site Selection

Data were collected at seven sites: four sites on Conetoe Creek, one on Crisp Creek and two sites on Ballahack Canal (Figure 5.1 and Table 5.1). Sampling sites were chosen for accessibility, proximity to benthic invertebrate sampling sites, and proximity to potential invertebrate stressor sources. These sites are briefly described below. Those sites that were monitored for benthic invertebrates were also described in Section 4.

Conetoe Creek at Penny Hill Road/SR 1409 (CTCC01). This site was located at the downstream end of the study area and served as the integrator station. Extensive chemical sampling occurred at this location. Benthic invertebrate sampling was conducted 1.6 miles upstream of this site due to nonwadable conditions at SR 1409. This site is also a DWQ Ambient Monitoring Station (station number 06205000).

Conetoe Creek at US Highway 64 Business (CTCC02). This site was located approximately two miles upstream of the integrator station (CTCC01) and approximately 1.25 miles downstream of the Bethel WWTP. The site is just upstream of the confluence of Ballahack Canal and Conetoe Creek and downstream of the confluence of Crisp Creek and Conetoe Creek. It served primarily as a bed sediment collection site and a data sonde station; however, limited water column sampling was also conducted. This was also a biological monitoring site.

Conetoe Creek at NC 42 (CTCC04). This site was located approximately six miles upstream from the integrator station (CTCC01) and is upstream of the confluence with Crisp Creek. This site was used only for data sonde deployment.

Conetoe Creek at Roberson School Road/SR 1527 (CTCC06). This sampling site was located approximately 8.5 miles upstream from the integrator station (CTCC01) and below the confluence of Conetoe Creek and Fountain Fork Creek. It is located below three swine farms, and the area surrounding the site contains a large percentage of agricultural activity. Since the study area was so large, this site was sampled with the same frequency and for the same parameters as the integrator station in order to allow a comparison of the upper and lower portions of the watershed. This site was approximately 0.5 miles downstream of the biological sampling location at SR 1510.

Crisp Creek at Roberson School Road/SR 1527 (CTCP02). This site was located on Crisp Creek approximately two miles upstream of its confluence with Conetoe Creek. It is approximately eight miles upstream from the integrator station (CTCC01) and was also a benthic monitoring site.

Ballahack Canal at NC 64 Business (CTBC01). This sampling site was located on Ballahack Canal approximately 1.25 miles upstream from the confluence of Ballahack Canal and Conetoe Creek and 0.33 miles upstream of the biological monitoring location (CTBC02). A data sonde also obtained data from this site.

Ballahack Canal at Burnett Farm Road/SR 1526 (CTBC03). This sampling site was located approximately 4.5 miles upstream from the confluence of Ballahack Canal and Conetoe Creek; 6.5 miles from the integrator station (CTCC01). This site was used only for data sonde deployment.

Table 5.1 Summary of Monitoring Approaches Used at Primary Sampling Sites

Station Code	Location	Monitoring Approach					
		Benthic Invertebrates	Water Chemistry	Toxicity (Water)	Bed Sediment	SPMD ³	Data Sonde ⁴
CTCC01	Conetoe Creek at Penny Hill Road/SR 1409	√ ¹	√ +	√		√	√
CTCC02	Conetoe Creek at US Hwy 64 Business	√	√	√	√	√	√
CTCC04	Conetoe Creek at NC 42	√				√	√
CTCC06	Conetoe Creek at Roberson School Road/SR 1527		√	√		√	√
CTCC07	Conetoe Creek at Thigpen Road/SR 1510	√					
CTCC08	Conetoe Creek at Cherry Hill Road/SR 1516	√					
CTBC01	Ballahack Canal at US Hwy 64 Business	√ ²	√	√		√	√
CTBC03	Ballahack Canal at Burnett Farm Road/SR 1526					√	√
CTCP02	Crisp Creek at Roberson School Road/SR 1527	√	√	√		√	

1. Benthic macroinvertebrate sampling site is about 1.6 miles upstream of SR 1409.
 2. Benthic macroinvertebrate sampling site is at NC 42, approximately 0.33 miles upstream of site US 64.
 3. SPMD is a semi-permeable membrane device used to detect organic contaminants over 7 to 11-day periods.
 4. Data sonde is a multi-probe field data recorder (3 to 7-day deployments).
- + Integrator station and DWQ Ambient Monitoring Station.

5.2 Water Quality Characterization

To provide an overall indication of the physical and chemical conditions in the Conetoe Creek watershed, the integrator station was sampled seven times during baseflow and twice during stormflow. Selected results are shown in Table 5.2 and are presented in more detail in Appendix B. Data from the ambient monitoring station (O6205000) are included for comparative purposes. Data from the ambient monitoring station can not be differentiated into storm or baseflow, but predominately represent non-storm events.

Table 5.2 Mean Values and Standard Errors for Field Parameters and Nutrients at Conetoe Creek at SR 1409*

<i>Parameter</i>	Study Data		Ambient Station Data (Station No. O6205000) May 2001 – May 2002
	Baseflow	Stormflow	
Dissolved Oxygen (mg/L)	7.26 ± 0.88 (7)	4.07 ± 0.00 (1)	6.78 ± 0.68 (13)
pH (Standard Units)	6.36 ± 0.12 (6)	6.41 ± 0.00 (1)	6.23 ± 0.12 (13)
Specific Conductance ($\mu\text{S}/\text{cm}$)	179.1 ± 9.5 (7)	186.3 ± 0.0 (1)	149.2 ± 6.4 (13)
Turbidity (NTU)	5.96 ± 0.70 (5)	4.45 ± 0.00 (1)	14.91 ± 11.04 (8)
Total Phosphorus (mg/L)	0.10 ± 0.02 (6)	0.07 ± 0.01 (2)	0.07 ± 0.02 (11)
Ammonia Nitrogen (mg/L)	0.21 ± 0.09 (6)	0.10 ± 0.00 (2)	0.16 ± 0.04 (11)
Total Kjeldahl Nitrogen (mg/L)	1.22 ± 0.25 (6)	0.90 ± 0.20 (2)	0.51 ± 0.11 (10)
Nitrate + Nitrite Nitrogen (mg/L)	1.33 ± 0.14 (6)	0.82 ± 0.51 (2)	1.80 ± 0.15 (11)

* The number of samples is in parentheses.

Specific conductance and nutrient levels at SR 1409 are elevated compared to background conditions (Caldwell, 1992) and other locations in the Tar-Pamlico River basin (NCDWQ, 1999). Baseflow total nitrogen concentrations average 2.55 mg/L. Substantial differences between ambient station data and baseflow data collected during this study were not apparent for dissolved oxygen, pH, specific conductance, total phosphorus and ammonia nitrogen. However, the Total Kjeldahl Nitrogen (TKN) was higher in this study's samples, and the nitrate-nitrite nitrogen and turbidity were higher in the ambient station data.

Though the number of storms sampled was limited, it is notable that nutrient concentrations were higher during baseflow than during the two storm events sampled. One of the storm samples was collected as water levels were declining.

5.3 Stressor and Source Identification

Since the benthic macroinvertebrate community throughout the study area showed indications of likely toxic impact (see Section 4), toxicity was evaluated at a number of locations. Water column toxicity was investigated using bioassays (acute and chronic), chemical pollutant monitoring (grab sampling for metals and pesticides), and deployment of SPMDs to sample organic contaminants. Results of this sampling are discussed in Section 5.3.1. Bed sediment at

CTCC02 was also studied for the presence of toxic conditions. Sediment toxicity assessment included: 42-day toxicity bioassays and chemical analyses for metals, pesticides, polychlorinated biphenyls, polycyclic aromatic hydrocarbons, and other organics. Sediment results are presented in Section 5.3.2. Dissolved oxygen and nutrient data are discussed in Section 5.3.3.

5.3.1 Water Column Toxicity

This section presents the results of bioassays conducted on water column samples, followed by a discussion of organic pollutants, metals, and other toxicants.

a. Bioassays

A total of fourteen long-term (chronic) bioassays for toxicity were conducted on baseflow samples on three occasions. A total of nine acute bioassays for toxicity were conducted during two storms at these same sites (Table 5.3).

All toxicity bioassays passed (Table 5.3), except for one chronic bioassay failure observed in a sample collected from Crisp Creek (CTCP02) on May 8, 2002 (Table 5.3). One hundred percent mortality of *C. dubia* occurred on the fifth day of the test. The cause of this failure is unclear. The only pesticide detected during this sampling event was the nematicide fenamiphos (trade name Namacur), which was detected at a concentration of 0.42 µg/L (Table 5.4). This concentration is well below the 1.3 – 14.4 mg/L range of EC₅₀s determined for *Daphnia magna* in 48-hour tests (see Appendix B). However, laboratory analysis was not available during the study for many of the pesticides commonly used on crops in this watershed (see below). Metals were also not analyzed on this date. The ammonia concentration on this date (0.20 mg/L) was the highest observed at this site, though still not at a level at which toxicity would be expected.

Table 5.3 Chronic and Acute Toxicity Bioassay of Water Column Samples¹

Date	Conetoe Creek at Penny Hill Road/ SR 1409 (CTCC01)		Conetoe Creek at US Hwy 64 Business (CTCC02)		Conetoe Creek at Roberson School Road/SR 1527 (CTCC06)		Ballahack Canal at US Hwy 64 Business (CTBC01)		Crisp Creek at Roberson School Road/SR 1527 (CTCP02)	
	Chronic Bioassay Baseflow	Acute Bioassay Stormflow	Chronic Bioassay Baseflow	Acute Bioassay Stormflow	Chronic Bioassay Baseflow	Acute Bioassay Stormflow	Chronic Bioassay Baseflow	Acute Bioassay Stormflow	Chronic Bioassay Baseflow	Acute Bioassay Stormflow
March 12, 2002		Pass				Pass		Pass		Pass
May 8, 2002	Pass				Pass		Pass		Fail²	
June 6, 2002		Pass		Pass		Pass		Pass		Pass
June 20, 2002	Pass		Pass		Pass		Pass		Pass	
August 8, 2002	Pass		Pass		Pass		Pass		Pass	

1. Blanks indicate that samples were not assessed for toxicity. Additional test data are in Appendix B Section 2.2.

2. 100% mortality occurred on day 5.

b. Pesticides and Organic Compounds

The Conetoe Creek watershed includes substantial crop acreage that receives regular applications of pesticides. At least one pesticide was detected in four of eight baseflow sampling events and in both storm samples (Table 5.4). Overall, eight different pesticides were detected in grab samples. Detections occurred throughout the watershed--in Ballahack Canal, in Crisp Creek, and in Conetoe Creek both upstream and downstream of these tributaries. Metolachlor was the most commonly detected pesticide, with atrazine, diuron, fenamiphos, metalaxyl, prometryn, terbufos and terbutol also detected. Organochlorine pesticides and polychlorinated biphenyls (PCBs) were not detected in grab samples.

Analytical laboratory capabilities available during the study encompass all pesticides. Of the 36 pesticides most commonly used on crops in the watershed (Table 2.8), laboratory analyses were available during the study for only 15. Pesticides for which analysis was not available are shown in Table 5.5. A complete listing of pesticides that were tested for is shown in Appendix B.

Published fresh water ecological screening benchmarks are unavailable for all of the detected pesticides except atrazine. Atrazine concentrations were well below EPA draft criteria levels (Great Lakes Environmental Center, 2001) of 12.35 µg/L (chronic) and 351.2 µg/L (acute). Concentrations of the other pesticides detected in the study area were several orders of magnitude below effects levels reported in the literature (see discussion in Appendix B).

Long-term monitoring with semi-permeable membrane devices (SPMDs) was conducted five times--during October 2001 and April, May, June and October 2002. Deployment periods ranged from seven to eleven days. SPMD concentrations represent an average concentration over the entire deployment period and are an excellent indication of the hydrophobic organic contaminants to which the sampling site was exposed. They do not provide information regarding pulse events, such as storms. Some precipitation fell during all deployment periods. Organic contaminants detected included, organochlorine pesticides, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and the current use pesticides chlorothanoni, chlorpyrifos, metolachlor and pendimethalin (pesticide and PCB data are summarized in Table 5.6; see Appendix B for additional data). Of these, only metolachlor was detected in grab samples. Chlorpyrifos in Ballahack Canal exceeded the national ambient water quality criteria screening value for chronic exposure and approached the acute screening value during the May sampling. None of the other organic contaminants exceeded individual screening values, but synergistic effects can not be discounted.

Table 5.4 Pesticides Detected in Water Samples from Conetoe Creek and Tributaries¹

Pesticide (µg/L)	May 9, 2001 (baseflow)				March 12, 2002 (storm)				May 8, 2002 (baseflow)			
	CTCC01	CTCC06	CTBC01	CTCP02	CTCC01	CTCC06	CTBC01	CTCP02	CTCC01	CTCC06	CTBC01	CTCP02
atrazine	0.021	-	0.016	0.035	-	-	-	-	-	-	-	-
diuron ²	-	-	-	-	-	-	-	-	-	-	-	-
fenamiphos	-	-	-	-	-	-	-	-	-	-	-	0.42
metolachlor	0.061	-	0.015	0.027	-	-	-	-	-	-	-	-
metalaxyl ²	-	-	-	-	*	-	-	-	-	-	-	-
prometryn	-	-	-	-	-	-	-	-	-	-	-	-
terbufos	0.016	-	-	0.039	-	-	-	-	-	-	-	-
terbutol ²	-	-	-	-	-	-	-	-	-	-	-	-

Pesticide (µg/L)	June 6, 2002 (storm)					June 20, 2002 (baseflow)					August 8, 2002 (baseflow)				
	CTCC 01	CTCC 02	CTCC 06	CTBC 01	CTCP 02	CTCC 01	CTCC 02	CTCC 06	CTBC 01	CTCP 02	CTCC 01	CTCC 02	CTCC 06	CTBC 01	CTCP 02
atrazine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
diuron ²	-	-	-	-	-	-	-	-	-	1.90	-	-	-	-	0.28
fenamiphos	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
metolachlor	0.170	0.310	0.051	0.210	6.400	0.097	0.130	0.056	0.330	-	-	-	0.085	-	0.210
metalaxyl ²	-	-	-	-	-	-	-	-	3.20	-	-	-	-	0.16	-
prometryn	-	-	-	-	-	-	-	-	-	-	-	-	0.870	-	0.330
terbufos	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
terbutol ²	-	-	-	-	-	-	-	-	-	-	-	-	0.15	-	0.10

1. A dash (-) indicates concentrations were below the detection limit of 0.005 µg/L. This table includes only sampling events in which at least one pesticide was detected. Samples were also collected at baseflow on 9/6/2001, 1/30/2002, 2/26/2002 and 4/9/2002 and analyzed for current use pesticides; all pesticides tested for on these dates were below the detection limit of 0.005 µg/L.
2. Pesticides were detected by Broad Scan GC/MS with a detection limit of 0.10 µg/L. An asterisk indicates that the pesticide was detected but concentrations were not determined.

Table 5.5 Commonly Used Pesticides for Which Laboratory Analysis of Water Samples Was Not Available During the Study*

1,3-dichlorpropene	carfentrazone	imazapic	metam sodium	thiodicarb
acifluorfen	clomazone	imidacloprid	paraquat	tribufos
aldicarb	dimethomorph	maleic hydrazide	spinosad	
azoxystrobin	ethephon	mancozeb	tebuconazole	
bentazon	glyphosate	mepiquat chloride		

* Based on list of pesticides commonly used in the Conetoe Creek watershed. See Section 2.

Table 5.6 Selected Pesticides and PCBs Captured on Semi-Permeable Membrane Devices, Part A¹

Pesticides and PCBs		10/10/2001 - 10/17/2001		3/29/2002 - 4/9/2002		5/9/2002 - 5/16/2002			6/12/2002 - 6/20/2002		NAWQC Chronic Screening Value (ng/L)	NAWQC Acute Screening Value (ng/L)
		CTCC01	CTCC06	CTCC01	CTCC06	CTCC01	CTCC06	CTBC01	CTCP02	CTCC04		
Organo- chlorine Pesticides	hexachlorobenzene	0.21	0.17	0.07						0.02	-	-
	heptachlor	1.53	1.36								3.8	520
	alpha-chlordane	2.02	1.61	0.05	0.03	0.06	0.04	0.13	0.04	0.02	4.3 ²	2400 ²
	gamma-chlordane	1.97	1.45	0.07	0.03	0.07	0.05	0.07	0.08	0.05	-	-
	trans-nonachlor		0.61	0.11	0.10	0.13	0.05	0.06	0.09	0.06	-	-
	dieldrin	0.66	0.71								56	240
	beta endosulfan	0.63									56	220
	endosulfan sulfate	0.64	0.34								-	-
	methoxychlor		0.16								30	-
	Sum of DDT's	12.13	7.66	1.38	1.09	1.60	0.30	1.74	0.71	0.44	-	-
Current Use Pesticides	chlorothalonil			0.08		0.18	0.17	0.10			-	-
	chlorpyrifos	0.86	1.10	7.08	1.10	7.65	0.71	73.99			41	83
	metolachlor	2.06	0.65								-	-
	pendimethalin							15.54			-	-
PCBs	Sum of PCBs	1.14	1.53	-	-	0.04	0.20	0.085	0.09	0.08	14	-

1. Concentrations are averages over the specified deployment periods. NAWQC = National Ambient Water Quality Criteria. Dashes (-) indicate that screening values were not available. Blanks indicate that values were below the detection limit of 0.025 ng/L.
2. Chronic and acute screening values are for chlordane.

Table 5.6 Selected Pesticides and PCBs Captured on Semi-Permeable Membrane Devices, Part B¹

<i>Pesticides and PCBs</i>		10/24/02 – 10/30/02						NAWQC Chronic Screening Value (ng/L)	NAWQC Acute Screening Value (ng/L)
		CTCC01	CTCC02	CTCC06	CTBC01	CTBC03	CTCP02		
Organo-chlorine Pesticides	hexachlorobenzene							-	-
	heptachlor							3.8	520
	alpha-chlordane	0.14	0.20	0.11	0.16	0.00	0.00	4.3 ²	2400 ²
	gamma-chlordane	0.08	0.14	0.00	0.12	0.00	0.00	-	-
	trans-nonachlor	0.11	0.14	0.08	0.15	0.00	0.00	-	-
	dieldrin							56	240
	beta-endosulfan							56	220
	endosulfan sulfate							-	-
	methoxychlor							30	-
	Sum of DDT's	2.83	3.98	1.81	4.22	0.91	1.78	-	-
Current Use Pesticides	chlorothalonil				1.69			-	-
	chlorpyrifos	4.08	2.72	2.64	11.51	1.11	1.87	41	83
	metolachlor							-	-
	pendimethalin				0.18			-	-
PCBs	Sum of PCBs	-	-	-	-	-	-	14	-

1. Concentrations are averages over the specified deployment periods. NAWQC = National Ambient Water Quality Criteria. Dashes (-) indicate that screening values were not available. Blanks indicate that values were below the detection limit of 0.025 ng/L.
2. Chronic and acute screening values are for chlordane.

c. Metals

Trace metals were commonly found in the Conetoe Creek watershed. Baseflow and stormflow data are shown in Tables 5.7 and 5.8, respectively. Baseflow and stormflow concentrations of aluminum exceeded the screening values in all samples. Iron also exceeded the screening values at the upstream sites on Conetoe Creek, Ballahack Canal and Crisp Creek. Iron concentrations at the integrator station on Conetoe Creek (CTCC01) were below the National Ambient Water Quality Criteria (NAWQC) values at both baseflow and stormflow. Silver concentrations exceeded the NAWQC values at Crisp Creek. The concentrations of copper exceeded the NAWQC value at the integrator station on Conetoe Creek in May 2002. Storm conditions did not increase the concentration of metals compared to baseflow.

Toxicity bioassays were not conducted on these samples except for the May 8, 2002 sample. Bioassays at CTCC01 and CTCC06 passed, despite exceedences of benchmarks for aluminum and copper at CTCC01 and aluminum and iron at CTCC06. These results suggest that metals concentrations were not sufficient to cause toxic impacts on these occasions.

Since total rather than dissolved concentrations of metals were measured, bioavailability is difficult to fully assess. Adjusting benchmarks for hardness only partially addresses this issue. Metals such as aluminum, iron, manganese, copper and zinc are widespread in North Carolina's waters. Potential effects on benthic macroinvertebrates are uncertain, since organisms in a given locality may be adapted to local concentrations. Comparison data on unimpaired coastal plain streams are limited, since many sites for which ambient data are available are either biologically impaired or are swamp waters that have not received a bioclassification. However, Contentnea Creek near SR 1800 at Grifton (ambient station J781000, in Pitt County) supports an adequate benthic community (bioclassification of Good-Fair), although median aluminum (370 µg/L), iron (1900 µg/L) and zinc (19 µg/L) concentrations all exceed median baseflow concentrations at CTCC01 and CTCC06 (NCDWQ, 2001a).

Table 5.7 Total Metal Concentrations at Baseflow and NAWQC Chronic Values**a. Ballahack Canal (CTBC01) and Crisp Creek (CTCP02)**

Metal	NAWQC ¹ Chronic Values (µg/L)	5/9/01 CTBC01 (µg/L)	5/9/01 CTCP02 (µg/L)
Aluminum	87	227	176
Arsenic	150	< 5	< 5
Cadmium	1.56 - 1.80	0.2	0.1
Chromium	11	1	1
Copper	5.68 - 6.62	3	2
Iron	1000	453	970
Lead	1.52 - 1.91	< 1	< 1
Manganese	120	29.1	15.5
Mercury	0.77	< 0.2	< 0.2
Nickel	31.94 - 37.17	< 1	6
Silver	0.36	< 0.5	0.8
Zinc	73.31 - 85.34	12.4	5.8
Hardness		67 mg/L	56 mg/L

b. Conetoe Creek Integrator Station at SR 1409 (CTCT01)

Metal	NAWQC ¹ Chronic Values (µg/L)	5/9/01 CTCC01 (µg/L)	1/30/02 CTCC01 (µg/L)	2/26/02 CTCC01 (µg/L)	4/9/02 CTCC01 (µg/L)	5/8/02 CTCC01 (µg/L)
Aluminum	87	199	423	313	531	288
Arsenic	150	< 5	< 5	-5	< 5	< 5
Cadmium	1.30 – 1.58	0.8	0.1	< 0.1	< 0.1	< 0.1
Chromium	11	< 1	< 1	< 1	< 1	< 1
Copper	4.89 - 5.77	< 1	< 1	< 1	1	6
Iron	1000	536	373	414	513	596
Lead	1.20 -1.56	< 1	< 1	1	< 1	< 1
Manganese	120	30.6	54	34	39	27
Mercury	0.77	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Nickel	27.00 – 32.42	2	< 1	1	1	< 1
Silver	0.36	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Zinc	61.00- 74.42	1.8	8	6.6	7.3	7.5
Hardness		51 mg/L	57 mg/L	47 mg/L	45 mg/L	50 mg/L

1. Manganese benchmark is Tier II, not NAWQC. Bold type indicates values exceeding benchmark. NAWQC values varied according to water hardness for cadmium, copper, lead, nickel and zinc. The range of values for the NAWQC is given for the hardness values measured.

Table 5.7 Total Metal Concentrations at Baseflow and NAWQC Chronic Values

c. Conetoe Creek at Roberson School Rd (CTCC06)

Metal	NAWQC ¹ Chronic Values (µg/L)	5/9/01 CTCC06 (µg/L)	1/30/02 CTCC06 (µg/L)	2/26/02 CTCC06 (µg/L)	4/9/02 CTCC06 (µg/L)	5/8/02 CTCC06 (µg/L)
Aluminum	87	238	525	327	696	247
Arsenic	150	< 5	< 5	< 5	< 5	< 5
Cadmium	0.88 – 1.20	0.1	< 0.1	0.1	< 0.1	< 0.1
Chromium	11	< 1	< 1	< 1	< 1	< 1
Copper	3.05 – 4.26	< 1	< 1	1	< 1	< 1
Iron	1000	2020	659	734	882	3050
Lead	0.60 – 0.99	< 1	< 1	< 1	< 1	< 1
Manganese	120	20.6	58	38	36	32
Mercury	0.77	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Nickel	17.23 – 24.03	< 1	< 1	1	1	< 1
Silver	0.36	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Zinc	39.51 – 55.12	3.5	7	9.8	5.5	2.4
Hardness		30 mg/L	40 mg/L	38 mg/L	30 mg/L	27 mg/L

1. Manganese benchmark is Tier II, not NAWQC. Bold type indicates values exceeding benchmark.. NAWQC values varied according to water hardness for cadmium, copper, lead, nickel and zinc. The range of values for the NAWQC is given for the hardness values measured.

Table 5.8 Total Metal Concentrations in Stormflows and NAWQC Acute Values at Conetoe Creek at Penny Hill Road/SR 1409 (CTCC01) and Conetoe Creek at Roberson School Rd (CTCC06)

Metal	NAWQC ¹ Acute Values (µg/L)	3/12/02 CTCC01 (µg/L)	3/12/02 CTCC06 (µg/L)
Aluminum	750	235	359
Arsenic	340	< 5	< 5
Cadmium	1.34 – 2.02	< 0.1	< 0.1
Chromium	16	< 1	< 1
Copper	5.06 – 7.15	< 1	< 1
Iron	NA ²	235	500
Lead	20.68 - 32.93	< 1	< 1
Manganese	2300	28	1
Mercury	1.4	< 0.2	< 0.2
Nickel	188-256	< 1	1
Silver	0.63 - 1.19	< 0.5	< 0.5
Zinc	48.03 – 65.47	2.3	< 0.1
Hardness		49 mg/L	34 mg/L

1. Manganese benchmark is Tier II, not NAWQC. Bold type indicates values exceeding benchmark. NAWQC values varied according to water hardness for cadmium, copper, lead, nickel and zinc. The range of values for the NAWQC is given for the hardness values measured.
2. NA = not applicable (no benchmark).

d. Chlorine

Total residual chlorine (TRC) concentrations were not analyzed during this study. TRC in the effluent of the Bethel WWTP averaged 0.23 mg/L during 2001 and 2002 (see Section 2), though monthly averages as high as 0.47 mg/L and daily concentrations as high as 0.95 were recorded during this period. The minimum flow at which discharge from the facility is allowed is 4.5 cfs (2.9 MGD) during November to April at the gage located (for most of this period) at SR 1409. If the facility discharges at the maximum permitted flow rate of 0.75 MGD (actual average discharge rate for the first six months of 2002 was 0.67 MGD) and streamflow is at the minimum allowable level, a dilution of approximately 4:1 results (the actual dilution at the discharge site would be somewhat less than this since Ballahack Canal enters Conetoe Creek between the outfall and the gage site. A 4:1 dilution of the maximum reported concentration of 0.95 mg/L yields an in-stream concentration in the range of the NC standard for TRC (0.17 mg/L) and EPA NAWQC (0.11 mg/L chronic and 0.19 mg/L acute). It appears that in-stream TRC levels are likely to exceed applicable benchmarks only under unusual circumstances at the effluent concentrations reported.

5.3.2 Bed Sediment Toxicity

a. Bioassays

Bed sediment toxicity and chemistry were evaluated at Conetoe Creek at Highway 64 Business (CTCC02) because the benthic community composition and *Chironomus* deformities at this location indicated potential toxic impacts (Section 4 and Appendix A). Sediments were collected in October 2001 and tested for toxicity using the amphipod *Hyallela azteca*. Although reproduction in the depositional sediments of Conetoe Creek appeared to be considerably below reproduction in the control sample, none of the test endpoints (28-day survival, 28-day growth, 35-day survival, 42-day survival, 42-day growth, and reproduction at 42 days) met statistical criteria for test failure (see Appendix B).

b. Pesticides and Organic Compounds

Chemical analyses conducted with these same sediments detected nine organic compounds (Table 5.9). A breakdown product of DDT (4,4'-DDE) was detected in a concentration very close to the conservative benchmark value. Four current use pesticides were detected in the depositional (fine) sediments, including simazine, which was not detected in the water column of Conetoe Creek. PCBs and PAHs were not detected. The semi-volatile compounds 3 & 4-methylphenol were present in both sandy and depositional sediments at concentrations within or exceeding the non-conservative benchmark range (benchmark is for 4-methylphenol).

Table 5.9 Organic Pollutants Detected in Bed Sediment, Conetoe Creek at Highway 64 Business (CTCC02)

Pollutant	Concentration (µg/Kg dry weight) in Sandy Sediment	Concentration (µg/Kg dry weight) in Depositional Sediment	Benchmark Values (µg/Kg) ¹		
			Conservative	Non-Conservative	EPA Region 4
Organochlorine Pesticides					
gamma Chlordane	ND	0.52	0.5 - 7 ²	4.79 - 171 ²	0.5 ²
4,4'-DDE	ND	1.41	1.2 - 8	7.81 - 171	1.2
Total DDTs	ND	1.41	1.58 - 7	46.1 - 4450	1.58
Current Use Pesticides					
Chlorpyrifos	ND	2.50	151		
Metolachlor	ND	4.20			
Prometryn	ND	3.00			
Simazine	ND	2.80			
Base/Neutral & Acid Organics					
Butylbenzylphthalate	202	190		63	
Di-n-Butylphthalate	1820	1740		55, 313.5 ³	
3 & 4-Methylphenol	469	986		100 - 670 ⁴	

ND indicates values below detection.

Blanks indicate that no benchmark is available

1 Benchmark values are adjusted for Total Organic Carbon (TOC) where appropriate. See Appendix B Section 1.2.

2 Benchmarks are for chlordane.

3 TOC adjusted benchmark is 55 µg/Kg for sandy sediment and 313.5 µg/Kg for depositional sediment.

4 Benchmark is for 4-methylphenol.

c. Metals

Five metals were detected in both sandy sediments and depositional sediments (Table 5.10). However, neither sandy nor depositional sediments contained metals concentrations exceeding conservative benchmark values.

Table 5.10 Metals Detected in Bed Sediment, Conetoe Creek at Highway 64 Business (CTCC02)

Metal ¹	Concentration (mg/Kg dry wt.) in Sandy Sediment	Concentration (mg/Kg dry wt.) in Depositional Sediment	Benchmark Values (mg/Kg) ²		
			Conservative	Non-Conservative	EPA Region 4
Aluminum	659.0	2250.0	25500	58030 to 73160	--
Copper	1.75	2.73	16 to 35.7	54.8 to 270	18.7
Iron	370.0	1090.0	20000 to 188400	40000	--
Manganese	4.5	3.1	460 to 1673	819 to 11000	--
Zinc	3.9	18.8	98 to 159	271 to 1532	124

1. Antimony, arsenic, beryllium, cadmium, chromium, lead, mercury, nickel, selenium, silver and thallium were not detected.
2. Conservative ranges ('no effects' benchmarks) are threshold values below which there is low probability of toxicity. Non-conservative ranges ('probable effects' benchmarks) are sets of values above which there is a high probability of toxicity. See Appendix B.

5.3.3 Dissolved Oxygen, Nutrients and Biochemical Oxygen Demand

a. Dissolved Oxygen

Dissolved oxygen (DO) was evaluated using two approaches. DO was measured in the field when water samples were collected for laboratory analysis. Additionally, data sondes provided data on daily DO cycles at several locations in the watershed.

Dissolved oxygen levels were highly varied throughout the Conetoe Creek watershed (Table 5.11). DO measured in static grab samples ranged from 2.78 mg/L (on June 20, 2002 at Conetoe Creek - CTCC06) to 11.35 mg/L (on February 26, 2002 at Ballahack Canal - CTBC01). The lowest minimum DO levels typically occurred in the upstream portion of the watershed. The highest DO levels observed were measured during the winter at each of the sites. Warm weather samples typically had DO measurements at or below 5 mg/L, with values below 3 mg/L recorded in Ballahack Canal and upper Conetoe Creek (CTCC06) during day time sampling.

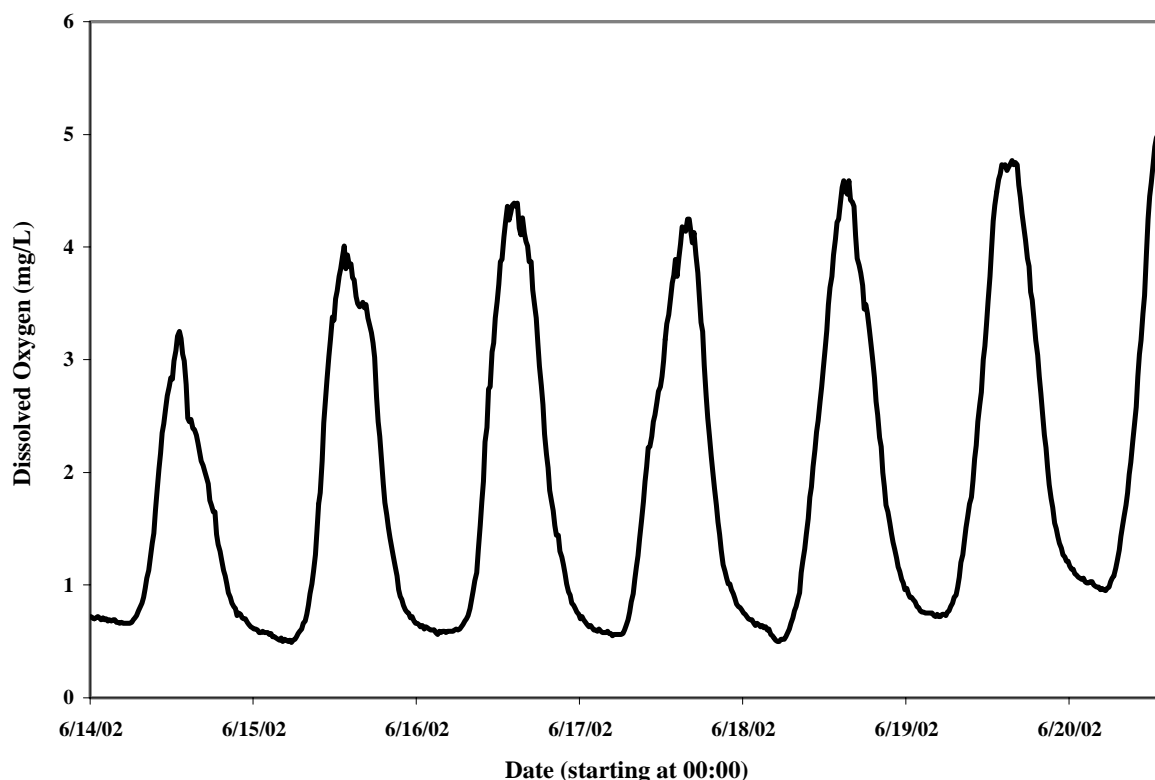
Continuous sampling (data sonde) conducted during June 2002 found DO concentrations that were consistently lower than the point measurements due to the inclusion of the overnight period. Typical diurnal fluctuations are shown in Figure 5.2 with DO concentrations peaking near mid-day and with a minimum just before dawn. CTCC02 is located about 1.25 miles below the Bethel WWTP outfall, but the facility was not discharging during the sampling period shown in Figure 5.2. In June 2002, overnight concentrations below 1 mg/L were observed in Ballahack Canal, Crisp Creek and some Conetoe Creek sites. Concentrations below 2 mg/L were recorded at all locations. These concentrations are low enough to have a negative impact on macroinvertebrate and fish communities.

Table 5.11 Dissolved Oxygen Concentrations (mg/L) from Static and Continuous Sampling

Site Code	Flow or Date	Mean Dissolved Oxygen	Minimum Dissolved Oxygen	Maximum Dissolved Oxygen	N
Static Sampling (Grab)					
CTCC01	Baseflow	7.26	4.82	10.27	7
	Stormflow	4.07			1
CTCC02	Baseflow	4.58	4.35	4.81	2
	Stormflow	4.16			1
CTCC06	Baseflow	6.99	2.78	10.31	7
	Stormflow	3.21			1
CTCP02	Baseflow	7.74	3.80	10.65	7
	Stormflow	4.98			1
CTBC01	Baseflow	7.01	2.82	11.35	7
	Stormflow	2.22			1
Continuous Sampling (Data Sonde)*					
CTCC01	3/29/02	5.23	4.27	6.60	873
	6/12/02	2.30	1.34	3.23	757
	6/20/02	2.50	1.69	3.60	370
CTCC02	9/17/01	4.97	3.50	6.47	672
	6/12/02	1.91	0.49	5.41	633
	6/20/02	2.54	0.55	6.07	372
CTCC04	6/12/02	2.94	1.64	3.94	764
	6/20/02	2.22	0.83	3.89	366
CTCC06	6/12/02	3.15	1.68	5.10	769
CTCP02	6/20/02	1.63	0.25	3.82	363
CTBC01	9/17/01	5.78	4.64	7.10	372
	6/20/02	2.24	0.55	6.19	368
CTBC03	6/12/02	2.90	0.17	6.23	727

* Mean represents average of measurements recorded at 15-minute intervals over multiday deployment.

Figure 5.2 Continuous Sampling of Dissolved Oxygen in Conetoe Creek at Highway 64 Business (CTCC02) from June 14, 2002 to June 20, 2002*



* Site CTCC02 is located about 1.25 miles below the Bethel WWTP outfall, but the facility was not discharging during the period over which observations were made.

b. Nutrients

As discussed above (Section 5.2), nutrient concentrations in Conetoe Creek at SR 1409 were well above background levels. This was true throughout the study area (Table 5.12). Mean concentrations at all sites far exceeded the 25th percentile values calculated by EPA for total phosphorus (0.023 mg/L) and total nitrogen (0.62 mg/L) in the inner coastal plain (Ecoregion 65) (USEPA, 2000c). The highest concentrations of all nutrients occurred in Ballahack Canal during both storm and baseflow conditions. Nutrient concentrations at the downstream end of the study area (CTCC01) are higher than upstream in Conetoe Creek and Crisp Creek, perhaps reflecting the influence of Ballahack Canal, which enters the mainstem just upstream of CTCC01. The lowest nutrient concentrations measured in the Conetoe Creek watershed were in the upper portions of Conetoe Creek (CTCC06) and in Crisp Creek (CTCP02). Baseflow concentrations were often higher than storm concentrations, which could reflect either the small number of storm samples collected or consistent non-storm inputs of nutrients (e.g., from groundwater containing high levels of nutrients). Baseflow mean concentrations in Ballahack Canal are particularly elevated: 0.15 mg/L total phosphorus; 0.48 mg/L ammonia; 2.83 mg/L total nitrogen.

Table 5.12 Mean Nutrient Concentrations (mg/L) and Standard Errors in the Conetoe Creek Watershed at Baseflow and Stormflow*

Nutrient	Sampling Location									
	CTCC01		CTCC02		CTCC06		CTBC01		CTCP02	
	Baseflow	Storm Flow	Baseflow	Storm Flow	Baseflow	Storm Flow	Baseflow	Storm Flow	Baseflow	Storm Flow
Total Phosphorus	0.10 ± 0.02 (6)	0.06 ± 0.01 (2)		0.05 (1)	0.06 ± 0.01 (6)	0.07 ± 0.04 (2)	0.15 ± 0.03 (6)	0.12 ± 0.07 (2)	0.05 ± 0.01 (6)	0.05 ± 0.02 (2)
Ammonia Nitrogen	0.21 ± 0.09 (6)	0.10 ± 0.00 (2)		0.1 (1)	0.18 ± 0.06 (6)	0.18 ± 0.12 (2)	0.48 ± 0.31 (6)	0.40 ± 0.30 (2)	0.11 ± 0.02 (6)	0.12 ± 0.08 (2)
Total Kjeldahl Nitrogen	1.22 ± 0.25 (6)	0.90 ± 0.20 (2)		0.9 (1)	1.02 ± 0.18 (6)	1.15 ± 0.55 (2)	1.45 ± 0.42 (6)	1.40 ± 0.40 (2)	0.78 ± 0.09 (6)	0.90 ± 0.10 (2)
Nitrate + Nitrite Nitrogen	1.33 ± 0.14 (6)	0.82 ± 0.51 (2)		0.15 (1)	0.54 ± 0.12 (6)	1.59 ± 0.45 (2)	1.38 ± 0.16 (6)	1.65 ± 0.57 (2)	0.74 ± 0.20 (6)	1.06 ± 0.41 (2)
Total Nitrogen	2.55 ± 0.37 (6)	1.72 ± 0.31 (2)		1.05 (1)	1.56 ± 0.18 (6)	2.74 ± 1.00 (2)	2.83 ± 0.54 (6)	3.05 ± 0.97 (2)	1.52 ± 0.21 (6)	1.96 ± 0.31 (2)

* Number of samples is in parentheses.

c. Biochemical Oxygen Demand

The biochemical oxygen demand (BOD₅) was measured on two occasions at a number of sites (Table 5.13). At the sites that were sampled regularly for water chemistry, BOD₅ concentrations ranged from 1.3 mg/L on Crisp Creek (CTCP02) to 2.1 mg/L on Ballahack Canal (CTBC01). The highest BOD₅ measurement was at the most upstream site on Conetoe Creek (CTCC09). However, this sample was collected in an area that was largely stagnant due to the low flow conditions common in the watershed during the spring and summer of 2002. The lowest BOD₅ concentration was recorded in the uppermost section of Crisp Creek.

Table 5.13 Biochemical Oxygen Demand (BOD₅) in the Conetoe Creek watershed (mg/L)

Date	Sampling Location ¹							
	Conetoe Creek Sites					Tributary Sites		
	CTCC01	CTCC02	WWTPU	CTCC06	CTCC09	CTCP02	CTCP10	CTBC01
May 8, 2002	2.0			1.6		1.3		2.1
August 22, 2002	1.9	1.4	2.9		6.6	1.5	0.6	

1. Blanks indicate that no samples were collected. Descriptions of site codes are given in Table 5.1 except for the following: WWTPU is on Conetoe Creek, approximately 1.5 miles upstream of Bethel's Wastewater Treatment Plant. CTCC09 is located on Conetoe Creek at NC 111/142, between CTCC07 and CTCC08. CTCP10 is in the upper portion of Crisp Creek, near the Edgecombe-Martin County line.

Section 6

Channel and Riparian Conditions

The characterization of stream habitat and riparian area condition at benthic macroinvertebrate sampling sites, described earlier, provides information essential to the assessment of conditions in the Conetoe Creek study area. However, a perspective limited to a small number of locations in a watershed may not provide an accurate picture of overall channel conditions, nor result in the identification of pollutant sources and specific problem areas. This study therefore undertook a broader characterization of stream condition by examining large sections of the Conetoe Creek channel network. This characterization is critical to an evaluation of the contribution of local and regional habitat conditions to stream impairment and to the identification of source areas and activities.

During the course of this study, project staff walked approximately 18 miles (29 km) of channel, including much of the Conetoe Creek mainstem between SR 1409 in Pitt County and NC 44 in Edgecombe County, much of Ballahack Canal between NC 42 and SR 1527 and selected reaches of Fountain Fork Creek and Crisp Creek. Some sections were surveyed on numerous occasions.

Project staff walked the identified sections of channel while carrying out the following tasks:

- Observing overall channel stability, noting specific areas of sediment deposition, severe bank erosion, evidence of channelization and similar attributes.
- Observing overall riparian area condition and the nature of surrounding land use.
- Identifying wastewater discharge pipes, stormwater outfalls, other piped inputs or withdrawals, and tributary inflows.
- Observing visual water quality conditions (odors, surface films, etc).
- Noting specific areas where pollutants are or may be entering the stream (livestock access areas, dump sites, land clearing adjacent to the stream, etc).
- Identifying specific areas that may be candidates for channel restoration or BMPs.
- Providing digital photo documentation of key features.
- Conducting formal habitat assessments at representative reaches, as appropriate.

This section summarizes channel and riparian conditions and discusses likely future changes in stream channels. Results of several geomorphic assessments conducted by North Carolina State University (NCSU) as a part of this study are also summarized.

6.1 Summary of Existing Conditions

6.1.1 Overall Channel and Riparian Condition

Channel Conditions. The entire length of Conetoe Creek's mainstem and all tributaries have been channelized and are deeply incised (Exhibits 6.1 and 6.2). As a result, channel morphology is extremely uniform, and streams in the watershed generally have little if any sinuosity. Channels are trapezoidal in shape and variability is limited. In part due to the considerable width

of the constructed channel, baseflow water depths are typically shallow except in the backwaters of impoundments.

Incised channels typically have stream banks that are higher, less stable and more prone to collapse and failure than those found in undisturbed channels. These features are particularly pronounced along Conetoe Creek's mainstem where stream banks are tall, steep and moderately to severely eroding. Banks are typically between eight and 15 feet high, although in some reaches, particularly downstream of NC 42, banks can reach 25 to 30 feet in height. Areas of bank erosion, bank failure and bank scour are common throughout the watershed (Exhibit 6.3, 6.4). Portions of a terrace run along one bank on most of the mainstem. Stream banks are usually poorly vegetated and substrate is comprised primarily of sand and mud.

The drainage network includes a large number of field ditches of varying size. The ditches, which drain active agricultural fields, are typically unbuffered. Field ditches are connected to larger drainage ditches, or "laterals", which drain to the mainstem or tributaries.

Two permanent impoundments, associated with irrigation withdrawal sites, are located in the study area. One of these is located on Ballahack Canal, just upstream of NC 42; and the second is located on Conetoe Creek, approximately one mile upstream of US Hwy 64 Alt. (Business). Massive algal blooms are common in the impounded portion of Ballahack Canal (Exhibit 6.5).

Riparian Conditions. The entire length of Conetoe Creek and its main tributaries are bordered by a drainage easement. The easement runs parallel to one side of the stream at a distance of approximately six to 12 feet from the top of the stream bank. The purpose of the easement is to provide equipment access for dredging and snagging activities. Although the easement is unpaved, it is kept clear of woody vegetation. Ongoing easement maintenance includes inspection, mowing and removal of obstructions.

A fairly wide forested area, comprised of mixed hardwoods and pine, borders the easements along much of Conetoe Creek, Crisp Creek and Fountain Fork Creek. Much of the riparian area on the side not bordering the easement is similarly vegetated. The most intact of these forested riparian areas is located along Crisp Creek (Exhibit 6.6), followed by the mainstem of Conetoe Creek and then Fountain Fork Creek. Riparian areas along Ballahack Canal, by contrast, either completely lack vegetation or have narrow vegetated strips. Along much of Ballahack Canal, crops are planted to the edge of stream banks (Exhibit 6.7).

Although stream bank vegetation is typically poor, mixed hardwoods ranging from approximately eight inches to two feet diameter are often present on terraces and bank slopes. Bank erosion and failure is often severe in reaches lacking forested riparian vegetation.

Aquatic Habitat. Habitat for aquatic organisms is highly degraded (Exhibit 6.8). Unlike many mountain and piedmont streams, coastal plain streams are typically sandy and lack coarser substrate or riffle habitat. In relatively undisturbed coastal plain streams, in-stream habitat typically consists of assorted woody debris, leaf packs and root mats. Snags and debris jams typically have higher species richness and productivity than other habitat types in coastal plain streams (Smock and Gilinsky, 1992). While leaf packs provide some organic habitat in Conetoe Creek and its tributaries, other critical habitat types have been substantially reduced by snagging

and bank erosion. Most pool habitats (other than impounded areas) are temporary, associated with woody debris that moves easily during storms or is removed during snagging.

The increased stream velocities associated with channelization and upland drainage can scour stream banks eliminating moderate bank undercuts and washing away small roots and other organic matter that would otherwise provide aquatic habitat. Stream bank scour is evident at numerous sites in the study area, particularly along the mainstem of Conetoe Creek between US Hwy 64 Alt. and SR 1409.

Low stream flows during the summer and early fall and, possible irrigation induced flow reductions, can further compromise habitat by exposing stream bank areas which might otherwise be submerged and available as habitat for aquatic organisms.

NCSU Assessments. As a part of this study, DWQ contracted with the Stream Restoration Institute at NCSU to conduct a morphological evaluation and restoration feasibility study of two reaches:

- Conetoe Creek at SR 1409. This reach, located at the downstream end of the study area, is typical of much of the mainstem.
- Ballahack Canal at SR 1526. This site typifies reaches with no riparian area or vegetative buffer between row crops and the stream.

These evaluations included a visual assessment of stream morphology, pebble counts, longitudinal and cross-sectional surveys, and other field activities. These evaluations are documented in two reports by NCSU (NCSRI, 2002a and 2002b). Table 6.1 summarizes basic geomorphic parameters for the two reaches. The NCSU assessments note the incised, channelized nature of these reaches, the uniform bed conditions and extensive bank erosion. The instability is especially notable in Ballahack Canal where mass bank failure and impending failure is common.

Table 6.1 Selected Geomorphic Characteristics of Three Reaches Evaluated by NCSU

	Conetoe Creek Upstream of SR 1409	Ballahack Canal Upstream of SR 1526
Width/Depth Ratio ¹	6.2	9.6
Entrenchment Ratio ²	5.5	6.9
D ₅₀ (mm) ³	sand	silt/clay
Slope (%)	0.28	0.025
Sinuosity ⁴	1.0	1.0
Rosgen Stream Type ⁵	E5	E6
Bank Height Ratio ⁶ (range)	1.3-1.5	1.7-2.1

Source: NCSRI 2002a & NCSRI 2002b

1. Bankfull width/mean bankfull depth

2. Floodprone area width/bankfull channel width

3. Median diameter of channel material (size class based on visual estimate)

4. Valley slope/channel slope

5. Rosgen (1996)

6. Low bank height/ max bankfull depth

6.1.2 Channelization and Hydrologic Impacts

Key features related to the hydrology of North Carolina's coastal plain region include low topography, poor drainage, a humid climate, large wetland tracts and a high water table.

The area's topography and gentle stream slopes result in relatively low velocity in unchannelized streams even during flood conditions. Unchannelized streams in this region typically have flat, broad forested floodplains (Kuenzler et al., 1977).

Although precipitation falls fairly evenly throughout the year, streamflow is lowest during summer and early fall due to high evapotranspiration during the warm growing season. Runoff from heavy summer rains and thunderstorms periodically increases stream stage enough to inundate the lower floodplain. During late fall and winter, most or all of the floodplain is submerged in natural streams.

Channelization and drainage of wetlands and adjacent areas change these conditions drastically. During channelization the natural stream channel is straightened, deepened and widened. This increases water velocity, allows the channel to contain floodwaters, drains the former floodplain, and lowers the water table on either side of the channel. A network of field ditches and laterals, connected to the larger channel, helps to draw down the water table and drain nearby low-lying areas. The increased relative depth of channelized streams also contributes to the maintenance of flow during summer months and increases the proportion of groundwater relative to surface runoff in the stream (Kuenzler et al., 1997).

Channelization impacts have been widespread in the Conetoe Creek drainage for many years. As discussed in Section 2, channelization has occurred on a number of occasions over the last two centuries, most recently in the 1960s. The straightening, deepening and widening of these streams has resulted in a uniform channel system with limited habitat diversity. Snagging and other maintenance activities contribute to ongoing habitat disturbance.

With the modification of sinuosity and slope and the creation of high stream banks, channelization often sets in motion an extended period of systemic instability characterized by channel incision and subsequent widening as the stream attempts to regain a stable morphology (Schumm et al., 1984; Brookes, 1988; Darby and Simon, 1999). These long-term processes can generate large amounts of sediment due to bed and bank erosion, resulting in highly unstable stream habitat, and increase the vulnerability of the stream to changes in watershed hydrology. While these processes are at work in the Conetoe Creek channel network, periodic maintenance activities serve to prevent the continued evolution of the channel and preserve its straight, relatively trapezoidal shape.

6.2 Future Changes

This channel system is systemically unstable. Were Conetoe Creek left undisturbed, natural geomorphic processes would widen the stream until its width was sufficient to allow for the stabilization of slumped banks and the eventual development of a new geomorphic floodplain within the incised channel (Schumm et al., 1984; Simon 1989; Simon and Darby, 1999). This would result in a more sinuous channel with improved habitat, but would likely result in the loss

of some adjacent land (due to the increased belt width required for a more sinuous stream) and potentially more frequent flooding.

In order to facilitate the continued drainage of the valuable agricultural lands in this watershed, local agencies have made a commitment to current channel maintenance practices. Increased meandering and other adjustment processes associated with stream recovery are not compatible with the practices now in use. Current maintenance practices, if carried out routinely over time, will effectively maintain the channel in approximately its current condition.

The increased stream slope created by channelization has led to incision, or deepening, of stream channels as well as to stream bed and bank scouring. Incised channels typically have stream banks that are higher, less stable and more prone to collapse and failure than those found in undisturbed channels. These features are particularly pronounced along Conetoe Creek's mainstem.



Exhibit 6.1 Conetoe Creek near SR 1409



Exhibit 6.2 Fountain Fork Creek, with drainage easement on left



Exhibit 6.3 Bank erosion and algal mats in Conetoe Creek.



Exhibit 6.4 Eroding banks along Conetoe Creek



Exhibit 6.5 Algal bloom in impounded portion of Ballahack Canal



Exhibit 6.6 Crisp Creek, showing riparian area and drainage easement on right



Exhibit 6.7 Ballahack Canal riparian area



Exhibit 6.8 Close-up of Crisp Creek illustrating lack of woody debris and bank habitat.
Foreground shows freshly fallen leaves on sand bars.

Section 7

Analysis and Conclusions – Causes and Sources of Impairment

Conetoe Creek is impaired for its entire length within the study area. This section analyzes the likely causes of this impairment, drawing upon the information presented earlier in this report. The sources or origin of these key stressors are also discussed.

7.1 Analyzing Causes of Impairment

The following analysis summarizes and evaluates the available information related to candidate causes of impairment in order to determine whether that information provides evidence that each particular stressor plays a substantial role in causing observed biological impacts. A strength of evidence approach is used to assess the evidence for or against each stressor and draw conclusions regarding the most likely causes of impairment. Causes of impairment may be single or multiple. All stressors present may not be significant contributors to impairment. [See the Background Note "Identifying Causes of Impairment", presented in Section 1, for additional discussion.]

7.1.1 A Framework for Causal Evaluation—the Strength of Evidence Approach

A ‘strength of evidence’ or ‘lines of evidence’ approach involves the logical evaluation of all available types (lines) of evidence to assess the strengths and weaknesses of that evidence in order to determine which of the options being assessed has the highest degree of support (USEPA, 1998; USEPA, 2000). The term ‘weight of evidence’ is sometimes used to describe this approach (Burton and Pitt, 2001), though this terminology has gone out of favor among many in the field because it can be interpreted as requiring a mathematical weighting of evidence.

This section considers all lines of evidence developed during the course of the study using a logical process that incorporates existing scientific knowledge and best professional judgment in order to consider the strengths and limitations of each source of information. Lines of evidence considered include benthic macroinvertebrate community data, habitat and riparian area assessment, chemistry and toxicity data, and information on watershed history, current watershed activities and land uses, and pollutant sources. The ecoepidemiological approach described by Fox (1991) and USEPA (2000) provides a useful set of concepts to help structure the review of evidence. The endpoint of this process is a decision regarding the most probable causes of the observed biological impairment and identification of those stressors that appear to be most important. Stressors are categorized as follows:

- **Primary cause of impairment.** A stressor having an impact sufficient to cause biological impairment. If multiple stressors are individually capable of causing impairment, the primary cause is the one that is most critical or limiting. Impairment is likely to continue if the stressor is not addressed. All streams will not have a primary cause of impairment. In some cases, a stream may have more than one primary cause of impairment where several

stressors are individually capable of causing impairment but no single stressor can be clearly identified as most important.

- **Secondary cause of impairment.** A stressor that is having an impact sufficient to cause biological impairment but that is not the most critical or limiting cause. Impairment is likely to continue if the stressor is not addressed.
- **Cumulative cause of impairment.** A stressor that is not sufficient to cause impairment acting singly, but that is one of several stressors that cumulatively causes impairment. A primary cause of impairment generally will not exist. Impairment is likely to continue if the various cumulative stressors are not addressed. Impairment may potentially be addressed by mitigating some but not all of the cumulative stressors. Since this cannot be determined in advance, addressing each of the stressors is recommended initially. The actual extent to which each cause should be mitigated must be determined in the course of an adaptive management process.
- **Contributing stressor.** A stressor that contributes to biological degradation and may exacerbate impairment but is not itself a cause of impairment. Mitigating contributing stressors is not necessary to address impairment, but should result in further improvements in aquatic communities if accomplished in conjunction with addressing causes of impairment.
- **Potential cause or contributor.** A stressor that has been documented to be present or is likely to be present, but for which existing information is inadequate to characterize its potential contribution to impairment.
- **Unlikely cause or contributor.** A stressor that is likely not present at a level sufficient to make a notable contribution to impairment. Such stressors are likely to impact stream biota in some fashion but are not important enough to be considered causes of or contributors to impairment.

7.1.2 *Candidate Stressors*

As outlined in Section 3, the primary candidate causes of impairment evaluated were:

- habitat degradation--lack of microhabitat;
- toxicity due to nonpoint source impacts; and
- organic and nutrient enrichment/low dissolved oxygen (DO).

7.1.3 *Review of Evidence*

Habitat degradation--lack of microhabitat. Habitat degradation was evaluated as a potential cause of biological impairment based on the long history of channel modification and an initial review of available habitat assessments, which indicated a lack of organic habitat. Relevant lines of evidence include benthic macroinvertebrate community data, habitat and geomorphic evaluation, and watershed history and characteristics.

The entire lengths of Conetoe Creek and its major tributaries were channelized (straightened and dredged) in the 1960s and on prior occasions (Sections 2 and 6). The channel is deeply incised. The limited sinuosity and uniform trapezoidal channel shape provides little physical diversity. Clearing and snagging following Hurricane Floyd was completed in September 2000, just months before the first benthic sampling for this study was conducted in November 2000 and February 2001.

Habitat was poor throughout the study area (Sections 4 and 6). Riffles were lacking, as would be expected for a coastal plain stream. However, the organic habitats critical to macroinvertebrates in this part of North Carolina were largely missing. While sticks and leaf packs were relatively common at most locations, other habitat types such as snags and root mats were rare and bank habitat was limited due to bank erosion and incision. Most deeper pool-like areas were associated with the backwaters of irrigation impoundments. The macroinvertebrate community was highly degraded at all sites (Section 4). EPT diversity was somewhat improved at one sample reach that included a riffle area (due to the presence of riprap), though overall habitat remained poor at this site. This provides evidence that improvements in habitat can lead to a more diverse benthic community. Two comparison streams sampled (Sasnet Mill Branch and Whichard Branch) had better habitat than Conetoe Creek and more diverse (though still degraded) benthic communities.

In summary, the amount of area suitable for colonization by benthic organisms was limited throughout the channel system, and the diversity of habitat types was limited as well. It is likely that habitat constraints play an important role in impairment of the benthic community in Conetoe Creek.

Toxicity due to nonpoint source impacts. Toxicity was evaluated as a cause of impairment because an initial review of the benthic community data for Conetoe Creek indicated potential toxic impacts. Relevant lines of evidence include: benthic community data; water chemistry data, toxicity bioassay data; sediment chemistry and bioassay data; and watershed characteristics.

Widespread impacts to the benthic community were evident (Section 4). Four of the seven sites sampled in the watershed had two or fewer EPT taxa, and stoneflies were found at only a single location. Midges and other tolerant taxa were also lacking at some locations. Macroinvertebrate numbers (total number of individuals collected) throughout the channel system were very low. These findings collectively suggest substantial toxic impacts. Additionally, indicator assemblages (midge community) at a number of sites also indicated likely toxicity. Finally, at the one location with sufficient *Chironomus* to conduct a midge deformity analysis (US 64 Business), a rating of Toxic-Poor indicated that toxic impacts to the benthic macroinvertebrate community were likely.

Intensive row crop agriculture is the dominant land use in the study area, and agricultural chemicals are widely used throughout the watershed.

Water column bioassays indicated the presence of acute toxicity in Crisp Creek during one of three baseflow sampling events. The cause of this toxicity could not be determined with the information available, although the pesticide fenamiphos was detected in this sample. Other bioassays conducted did not indicate toxic conditions at the time of sampling.

Grab samples and passive sampling devices detected numerous toxicants in the water column, many at relatively low concentrations. Eleven current use pesticides were detected during the study (Section 5). Screening benchmarks were available only for atrazine and chlorpyrifos. Average chlorpyrifos concentrations over one seven-day period (based on passive sampling device deployment) exceeded chronic screening values. Observed concentrations of the other compounds did not appear to exceed levels suggested by the literature as toxic (Section 5 and Appendix B). Aluminum commonly exceeded NAWQC throughout the watershed, and other

metals exceeded NAWQC on occasion (Section 5). Only total metals concentrations were analyzed and bioavailability could not be evaluated analytically, although bioassays did not indicate toxicity. Elevated aluminum levels are not unusual in North Carolina's waters (Section 5).

It is unlikely that the limited number of samples collected during the study captured the full variability in pollutant concentrations, and higher concentrations of pollutants probably periodically occur. Storm sampling was impeded by the low levels of precipitation during the study period (Section 2). It was not possible to completely characterize pesticides and their metabolites during the investigation. Laboratory analysis was not available during the study for 21 of the 36 pesticides most commonly used on crops in the watershed (Section 5), although only four of these are insecticides (aldicarb, imidacloprid, spinosad and thiodicarb). Other pesticides (e.g., herbicides and fungicides) probably pose a lower risk to benthic macroinvertebrates than do insecticides. For some analytes (see Appendix B) screening values were lower than laboratory detection limits. Whether these analytes were present in concentrations likely to be toxic is thus unknown. Analysis was also not available for most breakdown products. The presence of pesticide breakdown products in surface waters has not been widely studied and in most cases little is known regarding their toxicity (Larson et al., 1997). These chemicals can be present at high levels, however. One study conducted by the USGS found that herbicide breakdown products were commonly present in surface waters at concentrations an order of magnitude higher than the concentrations of parent compounds (Hamilton, 2002).

Toxic impacts, especially if caused by storm inputs, can be very episodic and difficult to identify. One cannot rule out toxicity due to the occurrence of spills or infrequent incidents that occurred between sampling events. Additionally, determining how laboratory toxicity bioassays apply to the in-stream context is sometimes not straightforward. While laboratory toxicity bioassays are useful in integrating the impacts of multiple pollutants (accounting for cumulative effects), laboratory conditions often will not reflect actual in-stream exposures (or other conditions) or account for the full range of biological responses (Burton and Pitt, 2001; Herricks, 2002). For example, stream organisms may experience multiple stresses over an extended period of time (such as repeated pulse exposures to various pollutants), a situation difficult to duplicate in laboratory bioassays. While difficult to assess, the long-term cumulative effects of frequent exposures is likely important (Burton and Pitt, 2001).

Sediment chemistry analyses and bioassays were performed on samples at US 64 Business. Chemical analyses identified several current use pesticides as well as organochlorine pesticides no longer registered for sale and metals. Concentrations were below the conservative benchmark range. The semi-volatile compounds 3 & 4-methylphenol were present at concentrations within or exceeding the non-conservative benchmark range. Long-term bioassay tests of these sediments did not indicate toxicity.

Evidence bearing on potential toxicity is diverse and difficult to synthesize. However, benthic community composition strongly suggests that toxic impacts are widespread in Conetoe Creek. Midge deformities at one site and a bioassay failure at another reinforce this conclusion. The specific pollutants responsible for this toxicity cannot be identified and may be variable.

Organic and nutrient enrichment/low DO. An initial review of DWQ benthic macroinvertebrate data revealed that benthic community assemblages were indicative of low DO conditions.

Primary watershed land uses (including extensive row crop production and swine operations) as well as the presence of a municipal wastewater discharge, also suggest the potential for organic and nutrient enrichment. Relevant lines of evidence are benthic community data and water quality monitoring data.

An analysis of benthic community indicator assemblages points to widespread impacts from enrichment and low dissolved oxygen in Conetoe Creek, Crisp Creek and Ballahack Canal (Section 4 and Appendix A). Low flow/intermittent stream indicators were particularly notable in the upper portion of the watershed (at and above SR 1510), though benthic community composition indicated the presence of nutrient enrichment at virtually all locations.

Monitoring of dissolved oxygen levels in Conetoe Creek and its tributaries provided evidence of low concentrations at a variety of times and locations. Daytime concentrations below 4 mg/L were observed at numerous sites (Section 5), and overnight concentrations below 2 mg/L were common in June 2002. DO concentrations as low as 0.17 mg/L were recorded. Nitrogen and phosphorus levels were elevated in the watershed. Although the biological response of streams to nutrient and organic loading is highly variable, and it is difficult to use in-stream nutrient concentrations to determine whether nutrients are a cause of benthic impairment, the confirmation of high nutrient concentrations serves to reinforce the benthic community and dissolved oxygen results.

It is difficult to differentiate between the impacts of organic and nutrient enrichment due to human activity, the potential contribution of naturally low DO levels, and the influence of the drought that occurred during 2001 and the first half of 2002, when most field work for the study was conducted.

- As discussed above and in Section 5, nutrient levels were elevated throughout the study area, and nitrate levels at the ambient station were the highest in the Tar-Pamlico River basin (NCDWQ, 1998). It does not seem likely that this situation is due to natural processes alone.
- It is clear that DO concentrations low enough to stress aquatic biota occur naturally in unimpacted coastal plain streams (Caldwell, 1992; Kuenzler et al., 1977), due in part to the swampy, low gradient nature of these systems. However, channelization can generally be expected to raise stream DO concentrations. In a study of three natural streams and four channelized streams (including Conetoe Creek) in the Pitt County area, Kuenzler et al. (1977) found that channelized streams better maintain minimum flows because of greater channel depth relative to the water table. DO concentrations in channelized streams were less seasonally variable than in natural streams. Summer DO concentrations below 2 mg/L were common in unchannelized streams, while DO in channelized streams seldom dropped below 5 mg/L. Most sampling was conducted in 1975, a wetter than average year (mean streamflow at the Conetoe Creek gage was 93 cfs vs. the long-term average of 79.9 cfs); and in 1976, a dry year (mean streamflow of 45 cfs at the Conetoe Creek gage). Low DO levels in the unchannelized streams occurred during both summers (Kuenzler et al., 1977). These results provide no evidence that the low DO concentrations observed in Conetoe Creek during the current study constitute normal conditions for channelized streams.
- The condition of the benthic community during the study was probably influenced to some extent by the ongoing drought, but cannot be attributed primarily to drought conditions (see Section 7.3). Several stations were sampled in 2000, a year with normal streamflow (see

Section 2), but the condition of the benthic community (Section 4) was similar to the subsequent drier period.

- The impact of dams and irrigation withdrawals is an additional confounding factor. Both the withdrawals and the dams themselves have the potential to worsen the impacts of organic loading or to lengthen the periods for which such impacts occur (see Section 7.3).

In conclusion, some low DO stress is probably natural in Conetoe Creek, especially at upstream sites draining relatively small areas. Drought conditions likely exacerbated the situation during the study. However, given the high nutrient levels and other factors noted above, it seems unlikely that observed dissolved oxygen concentrations and biological impacts are due solely to drought and natural conditions. Nutrient and organic enrichment are considered an important contributor to impairment.

7.1.4 Conclusion

Aquatic organisms in upper Conetoe Creek are heavily impacted by three critical stressors: toxic impacts, habitat degradation, and low dissolved oxygen due at least in part to nutrient and organic enrichment. The impact of each of these stressors appears to be severe, and the presence of any one of them at current levels may be sufficient to cause substantial degradation of aquatic biota. Toxicity and habitat degradation are considered to be primary causes of impairment. It is not possible to clearly prioritize their effects with the available information. Low DO/enrichment is also important and is considered a secondary cause of impairment.

7.2 Sources of Impairment

Toxicants. Based on the lack of sensitive species and the presence of indicator assemblages, toxicity appears to be widespread, indicating that the sources of toxicants most likely lie throughout the watershed. Agricultural pesticides are the only plausible widespread source of potential toxicants in the study area, which is dominated by row crop agriculture. There are many pathways by which pesticides may potentially reach stream channels (National Research Council, 1993). Data collected during this study are not sufficient to evaluate which pathways are most important in the Conetoe Creek drainage.

The Bethel WWTP is another potential source of toxicants. While the facility primarily discharges treated domestic wastewater and likely contains a limited range of toxicants compared to facilities with more diverse waste streams, chlorine toxicity is plausible in the area below the discharge, at least under unusual conditions (Section 5). Because of the volatility of chlorine, these localized impacts, should they exist, likely do not extend to the gage site at SR 1409, which is located approximately three to four miles below the outfall. The benthic monitoring site 1.25 miles below the discharge had the most diverse EPT community in the watershed (though overall biological condition was still quite impacted), providing no evidence that biological conditions worsen downstream of the outfall. Though sporadic and localized chlorine impacts are possible, it is not likely that the discharge is the primary source of toxic inputs, even for lower Conetoe Creek.

Habitat degradation. Habitat degradation in Conetoe Creek stems primarily from hydromodification. EPA defines hydromodification (source category 7000) as the alteration of

the hydrologic characteristics of surface waters resulting in degradation of resource conditions (USEPA, 1997). Channelization (alteration of channel morphology, dredging), along with subsequent clearing and snagging operations, are clearly the dominant types of hydromodification in the study area and the reason for degraded habitat conditions. In addition to the direct disturbance it entails and the loss or inaccessibility of bank habitat due to erosion and incision, the morphological simplification of the constructed channel makes it more difficult for the system to retain woody debris. Snagging operations obviously serve to further worsen the situation by directly removing woody material from the channel. Clearing and snagging following Hurricane Floyd was completed in 2000, only a few months prior to the first benthic community samples collected during the project.

Organic and nutrient enrichment/low dissolved oxygen. As noted above, low DO conditions may be impacted by drought, dams and irrigation withdrawals, as well as by pollutant inputs. The discussion below focuses on nutrient and organic loading. Specific contributors of nutrients and organic inputs were not evaluated. Since nutrient levels are high in many locations in the study area; however, it is clear that loadings to Conetoe Creek come from multiple sources, most likely the row crop and confined animal operations located throughout the watershed. The drainage systems used on most cropland can allow considerable nitrogen loss from fields, much of which can reach streams if effective water management practices are not utilized. The lack of vegetated buffers along ditches also contributes to nutrient losses. Confined animal operations may potentially contribute organic loading if lagoons and waste spraying operations are not properly managed. Over the past decade, the capacity of swine operations in the study area has increased by a factor of ten (Section 2). While swine operations may be a source of organic and nutrient loading in the Conetoe Creek watershed, this cannot be confirmed with the limited sampling carried out during the project (Section 5). Ballahack Canal, with the highest nutrient concentrations in the study area, has no swine operations in its drainage area. Upper Conetoe Creek (CTCC06, at SR 1527), with three active swine operations in its watershed, has baseflow nitrogen concentrations comparable to Crisp Creek, which has only one, though nitrogen concentrations during storms are higher at CTCC06.

Riparian vegetation along much of Ballahack Canal is limited. Riparian buffers are the poorest in the study area and are inadequate to protect the stream from nutrient inputs. Cultivated areas extend virtually to the top of the stream bank in some areas. The lower portion of the Ballahack Canal watershed contains the highest concentration of septic systems in the study area, but the chemical monitoring station on this stream was located upstream of most development. It does not appear likely that septic systems are the major contributor to the high nutrient levels observed in this stream. The Greenleaf Nursery is also located in the Ballahack Canal watershed, although available data do not establish that this operation impacts in-stream nutrient levels.

Nutrient and BOD concentrations in the effluent of the Bethel WWTP are high, but the WWTP discharges only intermittently. Low DO levels are evident below the outfall, but concentrations there are no lower than in other parts of the watershed. The downstream benthic monitoring site closest to the discharge had the highest benthic community diversity in the watershed, providing no evidence that the discharge is causing additional deterioration. Bethel is required under a Special Order by Consent to eliminate its discharge from Conetoe Creek and connect to Greenville's wastewater treatment system.

7.3 Other Issues of Concern

Drought. As discussed in Section 2, streamflows and precipitation in Conetoe Creek were below normal during much of the study period, although the current drought has generally been less severe in the Conetoe Creek area than in the piedmont and western coastal plain (see Southeast Regional Climate Center at <http://water.dnr.state.sc.us/climate/sercc/>). While it is likely that lower than normal streamflows had some impact on the conditions of the biological community observed during this study, it is not likely that the impoverished state of stream biota can be attributed entirely or primarily to drought. Biological sampling conducted by DWQ in the Tar Pamlico River Basin and other areas of eastern North Carolina over the past several years has found numerous locations where the benthic community is considerably more diverse than in Conetoe Creek (DWQ Biological Assessment Unit data). Low summer streamflows are not unusual in Conetoe Creek, even at more normal precipitation levels. While below normal precipitation may negatively impact dissolved oxygen levels, it would also be expected to lessen storm-driven loading of nutrients and pesticides to the channel system.

Impoundments and irrigation withdrawals. Irrigation water is withdrawn from Conetoe Creek and its tributaries at a number of locations (Section 2). Little is known about these withdrawals and they were not specifically investigated during the study. It is possible, however, that these withdrawals may collectively reduce streamflows and available habitat area during dry summer periods, when both natural low stream discharge and irrigation withdrawals are likely. The dams constructed for purposes of facilitating these withdrawals may also worsen enrichment impacts by slowing water velocity and reducing the assimilative capacity of the stream. Because of the low stream gradient and the high stream banks in this system, even dams confined to the channel can create stagnant backwater areas extending a mile or more upstream from the dam.

Recolonization sources. Limited recolonization potential from within the watershed is a concern. Downstream drift of benthic organisms is an important mechanism for the maintenance of benthic macroinvertebrate populations, allowing for more rapid recovery from disturbance than other mechanisms such as aerial recolonization. The lack of quality upstream sources of colonization thus contributes to biological degradation in downstream portions of Conetoe Creek by altering the balance between disturbance and recovery (see the Background Note "The Stress-Recovery Cycle").

Broader impacts. Sediment, nutrients and toxicants from Conetoe Creek are transported to the Tar River and the Pamlico River estuary where they can have negative resource impacts. Nitrogen and phosphorus levels documented in the study and in previous analyses of ambient data from the watershed (NCDWQ, 1998) indicate that Conetoe Creek is an important source of nutrients to the Tar River.



Background Note: The Stress-Recovery Cycle

Even in relatively pristine streams, aquatic organisms are exposed to periods of stress. Natural stresses due to high flows during storms, low flows during hot dry summer periods or episodic large sediment inputs (e.g., from slope failures in mountain areas or breaching of beaver dams) can have significant impacts on stream communities. Although aquatic communities in high quality streams may be impacted by such disturbances, and some species may be temporarily lost from particular sites, populations are able to reestablish themselves--often very quickly--by recolonization from less impacted areas or refugia (see Yount and Niemi, 1990; Niemi et al., 1990). This process can involve recolonization from backwater areas, interstitial zones (spaces between the cobble and gravel substrate), the hyporheic zone (underground habitats just below the stream bed surface layer) or other available microhabitats. Repopulation from headwaters or tributary streams not impacted by the disturbance can also occur. For insects aerial recolonization is important as well.

Without robust mechanisms of recovery, even streams subjected to relatively modest levels of disturbance would be unable to support the diversity of aquatic organisms that they often do (Sedell et al., 1990; Frissell, 1997). This balance between local elimination followed by repopulation is critical to the persistence of fish, macroinvertebrates and other organisms in aquatic ecosystems, and is part of what we mean when we say that these creatures are "adapted" to their environment.

It is now commonly recognized that as watersheds experience increased human activity, stream biota are subjected to higher levels of stress. This can include both an increased frequency, duration or intensity of 'natural' types of disturbance, such as high flows, as well as completely new stresses, such as exposure to chlorinated organic chemicals. We less often realize, however, that many of these same activities often serve to inhibit those mechanisms that allow streams to recover from disturbances--in particular movement and recolonization (Frissell, 1997). For example, as watersheds develop:

- channel margin and backwater refugia may be eliminated as bank erosion or direct channel modification (channelization) make channel conditions more uniform and habitat less diverse;
- edge habitat, such as root mats, may be unavailable to biota due to lowered baseflows;
- access to interstitial and hyporheic areas may be limited by sediment deposition;
- impoundments may limit or eliminate drift of organisms from upstream;
- small headwater and tributary streams may be eliminated (culverted or replaced with storm drain systems);
- remaining headwater and tributary streams may be highly degraded (e.g., via channelization, removal of riparian vegetation, incision and widening due to increased stormflows, or decreased baseflows);
- aerial recolonization of macroinvertebrates may be diminished by the concomitant or subsequent degradation of streams in adjacent watersheds; and
- fish migration is often limited by culverts or other barriers.

As human activity intensifies, aquatic organisms are thus subjected to more frequent and more intense periods of stress, while at the same time their ability to recover from these stresses is severely compromised. It is the interaction between these two processes that results in the failure of many streams to support an acceptable population of fish or macroinvertebrates.

Efforts to restore better functioning aquatic communities in degraded streams must consider strategies to both reduce the stresses affecting stream biota and to protect and restore potential refugia and other sources of colonizing organisms. Under some conditions, the lack of adequate recolonization sources may delay or impede recovery. Protecting existing refugia and those relatively healthy areas that remain in impacted watersheds should be an important component of watershed restoration efforts (McGurrin and Forsgren, 1997; Frissell, 1997).

Section 8

Improving Stream Integrity in Upper Conetoe Creek: Recommended Strategies

As discussed in the previous section, upper Conetoe Creek is impaired by the impacts of toxicity, habitat degradation, and low dissolved oxygen/organic-nutrient enrichment. This section discusses how these problems can be addressed. A summary of recommendations is included at the end of the section. Since most of the study area lies within an agricultural area in which land use is relatively stable, the potential impacts of future development are not a significant concern at present.

8.1 Addressing Current Causes of Impairment

The objective of efforts to improve stream integrity is to restore water chemistry and habitat conditions to support a more diverse and functional biological community in Conetoe Creek. Because of the widespread nature of biological degradation, the long history of channel and drainage modification, and the intensity of agricultural activity in the watershed, bringing about substantial water quality improvement will be a tremendous challenge. Yet the watershed has not been so highly modified as to preclude improvements in stream integrity. A return to the relatively unimpacted conditions that existed prior to widespread agriculture is unlikely, but Conetoe Creek can potentially support a healthier biological community than it does today. Additionally, the quantities of nutrients and other pollutants transported to the Tar River can be reduced.

As discussed in Section 7, while the key factors causing impairment in upper Conetoe Creek have been identified, their interrelationship remains unclear. Additionally, there are inherent uncertainties regarding how individual BMPs cumulatively impact receiving water chemistry, geomorphology and habitat (Shields et al., 1999; Urbonas, 2002), and in how aquatic organisms will respond to improved conditions. For these reasons, the intensity of management action necessary to bring about a particular degree of biological improvement cannot be established in advance. This section describes the types of actions needed to improve biological conditions in Conetoe Creek, but the mix of activities that will be necessary – and the extent of improvement that will be attainable – will only become apparent over time as an adaptive management approach is implemented (see Section 8.3).

8.1.1 *Toxic Impacts*

Agricultural pesticides are the most likely cause of widespread toxic impacts in this watershed. Long-term impacts of repeated exposures are probably important, and the most critical toxicants may vary with time, associated with specific events or seasonal activities as well as with changes in pesticide usage. Source areas likely lie throughout the watershed.

For a variety of reasons (Sections 5 and 7), the presence of pesticides and their metabolites in the surface waters of this watershed remains incompletely characterized, limiting the types of recommendations that can be made at this point. While biological evidence of toxic impacts is

widespread, the specific pesticides of primary concern remain unclear, as do the mechanisms by which these pollutants are likely reaching Conetoe Creek and its tributaries. Fate and transport processes for pesticides can be complex (e.g., see National Research Council, 1993), and key pathways can include aerial drift, volatilization, surface runoff and groundwater leaching. Key factors in the study area could include: inappropriate use (e.g., application of pesticides closer to surface waters than allowed by regulations); misapplication (e.g., timing or rate of application not appropriate); or mixing, storage or disposal problems.

The first step in addressing pesticide issues in this watershed is to obtain a better understanding of the nature of the problem, including the specific practices in use. The necessary investigation is best undertaken by the appropriate agricultural agencies, in cooperation with local farmers, university researchers (e.g., the NCSU Cooperative Extension Service) and DWQ. Relevant agricultural agencies include the NC Department of Agriculture and Consumer Services (NCDACS), the NC Division of Soil and Water Conservation, local Soil and Water Conservation Districts and the US Department of Agriculture Natural Resources Conservation Service. This investigation should likely include a review of current pesticide usage and application practices in the watershed and may involve additional water sampling.

This investigation should be used as the basis for determining what specific actions are necessary to reduce pesticide impacts. In the short run, funding from the CWMTF may be able to facilitate this planning effort. Funding for additional sampling may be available from the Pesticide Environmental Trust Fund administered by the NCDACS. Funding of specific BMPs can be considered in the longer term, although NC Agriculture Cost Share Program funding may also be available for BMP implementation.

8.1.2 Habitat Degradation

Habitat degradation in the study area is manifested in the lack of organic habitat, especially snags and large woody debris, and the lack of diversity in channel planform and cross-sectional dimensions. From a biological perspective, the most effective approach would be to restore the channel to a more natural condition. Stream channel restoration involves reestablishing a stable channel dimension (cross-section), pattern (sinuosity and planform) and longitudinal profile (slope). While other options exist (see NCSRI 2002a and 2002b), the most feasible approach to the restoration of channels in this watershed is probably to construct appropriate floodplain area and channel form within the existing incised channel (Rosgen priority 2 or priority 3 approach). The specific restoration strategy selected would depend upon the stream corridor width available (belt width), among other factors (NCSRI, 2002a and 2002b; Rosgen, 1997).

Based on the recent experience of the North Carolina Wetlands Restoration Program (Haupt et al., 2002) and NCSU estimates (NCSRI, 2002a and 2002b) of about \$100 per linear foot (about \$0.5 Million per mile) should be expected for the restoration of rural stream channels. Channel restoration in Conetoe Creek would be a massive undertaking. The channel work of the 1960s, which large scale restoration would in effect undo, covered 95 miles in the Conetoe Creek drainage, including those portions of the watershed downstream of the study area.

Large scale channel restoration is likely to be viewed unfavorably by watershed residents and local agency personnel because of potential negative impacts on agricultural activities. For this

reason alone, such restoration may not be feasible. An alternative approach would be to focus on habitat improvement efforts that are consistent with the current channelized condition of the stream. The key objective of such a strategy must be the improvement of organic habitat, in particular increasing the availability of large woody debris, which currently is largely absent from the channel system. Large wood is not only critical habitat in its own right, but is essential to the trapping of smaller organic material (e.g., leaf packs and twigs) and the retention of those microhabitats within the system. Given the existence of forested areas along many channels, the easiest way to accomplish this is to limit the removal of woody material from stream channels.

Conditions during the study period may represent worst case conditions as far as woody material in the channel is concerned. Clearing and snagging following Hurricane Floyd, completed in September 2000, was extremely thorough, leaving virtually no wood in stream channels. How this work compared to more routine clearing and snagging (work not related to catastrophic events) is not clear. It is apparent, however, that future operations must be conducted in a much more sensitive manner than the last project if better habitat is to be maintained in Conetoe Creek.

Current NRCS guidelines for clearing and snagging (NRCS Practice Code 326) do not specifically discuss the relationship between woody material and aquatic habitat in coastal plain streams (NRCS, 2002). Certainly some clearing and snagging may be necessary to insure that channel blockage does not occur, but it is likely that leaving more wood in the stream than remained following recent snagging operations could enhance habitat without substantially increasing flood potential. How this would impact maintenance costs is unclear. More frequent inspections would be required, but the total amount of material that would have to be removed would decline.

Future operations should generally be confined to removing major blockages of the stream channel. Edgecombe County Drainage District #2, NRCS and DWQ should work to develop clearing and snagging guidelines for Conetoe Creek that will provide for improved in-stream habitat while still ensuring adequate drainage. Training and oversight of contractors should be one component of this effort. For those operations requiring a Section 401 Water Quality Certification, DWQ will closely examine potential impacts on aquatic habitat and work to ensure that these impacts are minimized.

Riparian areas are poorly vegetated along much of Ballahack Canal. Reestablishment of woody riparian vegetation is probably necessary to ensure an adequate supply of woody material to this tributary stream. While establishment of forested riparian buffers presents certain challenges (see discussion below), the practice would receive substantial nutrient reduction credit under the Tar-Pamlico agriculture rule and it is a cost shared practice under several programs. Establishment of woody riparian vegetation (or herbaceous vegetation where woody vegetation is impractical) should also be encouraged throughout the watershed in areas where riparian zones lack or have only limited amounts of such vegetation. In addition to supplying woody material to the stream, properly functioning riparian areas can also serve to reduce inputs of nutrients and other pollutants.

8.1.3 *Organic and Nutrient Enrichment*

Reducing agricultural nutrient and BOD sources is the key to minimizing enrichment problems in the Conetoe Creek watershed. Other sources (e.g., the Bethel wastewater discharge and septic systems) are of less importance, and removal of the WWTP discharge from Conetoe Creek is scheduled to occur within the next year.

Agricultural operations in the area are currently subject to the Tar-Pamlico basin agriculture rule. While that rule (along with several other regulations) was intended to reduce nutrient loading to the estuary, rather than address impacts in particular streams, it would clearly be most efficient to work within the framework of the Tar-Pamlico agriculture rule as much as possible in seeking nutrient reductions in Conetoe Creek.

The rule became effective September 1, 2001. Over the past year a Basin Oversight Committee (BOC) was established. Local Advisory Committees (LAC) have formed (county level) and have begun registering farmers as required by the rule. Local plans detailing how a 30% reduction in nitrogen loading will be obtained have yet to be developed. The LACs in the counties within the Conetoe Creek watershed will be developing specific county nutrient reduction strategies tailored to local conditions by August 2003.

While DWQ does not wish to make recommendations here that would short circuit this process, it is important that the LACs operative in the Conetoe Creek watershed consider a number of factors in developing nutrient strategies. Most importantly, LACs have considerable discretion in how the overall county nutrient reduction goals are addressed. Greater reductions could be sought in some watersheds within a county and lesser reductions within others. Given current nutrient impacts in Conetoe Creek, it is critical that the Conetoe Creek watershed be given priority status for the implementation of nutrient reduction measures.

Many field ditches in the watershed appear to lack adequate vegetative buffers. Increased use of vegetative filter strips, riparian herbaceous cover, field borders or other practices along these ditches would have a high potential for reducing nutrient inputs. Riparian forest buffers, where they would not impede irrigation practices, would both provide greater nutrient removal than herbaceous buffering practices and serve as a source of woody debris for channel habitat. Cost share is available for all of these practices.

Controlled drainage can effectively reduce nitrogen export from agricultural fields, in large part by reducing total runoff volume (Evans et al., 1989). The use of controlled drainage is common in the watershed, but the manner in which these structures are managed merits evaluation to determine if opportunities exist to improve water management in order to reduce nutrient exports that are compatible with agricultural production goals. Water control structures must be managed year-round, not just during the growing season, for effective water quality improvement (Evans et al., 1996; Gilliam et al., 1997) and the intensity of management is critical to the effectiveness of these practices in reducing nitrogen exports. Further, to receive credit under the agriculture rule, water control structures must be managed to maximize nitrogen and phosphorus removal throughout the year.

As part of the implementation of the Neuse River basin agricultural rule, nutrient management plans have been implemented on a widespread basis. It is likely that this tool will be important in the Tar-Pamlico basin as well.

The extent of nutrient reduction that will be necessary to reduce stress to aquatic organisms in Conetoe Creek is unknown. The creek should be monitored as practices are implemented under the Tar-Pamlico basin agriculture rule to document the extent of improvement and determine if additional actions are necessary.

Much of the cropland in the watershed is rented via short-term (often one-year) leases. For some BMPs, like water control structures and forested buffers, this may be an impediment to BMP implementation. The implementation of BMPs under the Tar-Pamlico agriculture rule should be monitored to assess this issue and determine if changes in rule language or implementation policies are warranted to facilitate the installation of BMPs on rented land. Outreach efforts to educate owners of rented land regarding the importance of nutrient reduction efforts should be encouraged and supported. For some structural BMPs, it may be important for LACs to provide guidance to renters on the types of arrangements to establish with owners, for example arrangements similar to those used in permanent agreements under CREP (Conservation Reserve Enhancement Program).

8.1.4 Impoundments and Irrigation Withdrawals

On-stream impoundments and irrigation withdrawals, while not specifically examined during this study, may negatively affect dissolved oxygen levels in Conetoe Creek and exacerbate the impacts of nutrient and organic loading (Sections 2.2 and 7.3). Irrigation needs are likely to be greatest during the summer when natural stream discharge is low. These potential impacts merit further investigation. The construction of new on-stream impoundments and the withdrawal of additional irrigation water should be discouraged until a study of the impacts of these activities on streamflows and dissolved oxygen levels can be completed.

8.2 Addressing Future Threats

The study area is largely undeveloped and is likely to remain that way for the foreseeable future. Development pressures are light in the area. Edgecombe County lost population between 1990 and 2000 (Section 2), a situation that is expected to continue. Development thus does not pose a substantial threat to water quality in the upper Conetoe Creek watershed. Should development occur in the future, however, effective stormwater management will be critical, since streams are highly incised and likely to be extremely vulnerable to changes in watershed hydrology (Bledsoe and Watson, 2001).

8.3 A Framework for Improving and Protecting Stream Integrity

Watershed restoration of the type necessary to significantly improve Conetoe Creek is clearly ambitious, but has become more common over the past decade. Local governments and watershed-based organizations have increasingly sought to plan and implement long-term restoration and management strategies that integrate channel, riparian and watershed measures to

address stream issues in an integrated fashion. Restoration projects of this scale require an iterative process of ‘adaptive management’ (Reckhow, 1997; USEPA, 2001). Considering the scope of activities, logistical complexities and scientific uncertainties, it is not possible to anticipate all necessary actions in advance. An initial round of management actions must be planned and implemented, the results of those activities monitored over time, and the resulting information used as the basis for planning subsequent efforts. Additional measures should be implemented as appropriate. Improvement in stream condition is likely to be incremental.

An organizational framework for ongoing watershed management is essential in order to provide oversight over project implementation, to evaluate how current restoration and protection strategies are working, and to plan for the future. While state agencies must play an important role in this undertaking, planning is often more effectively initiated and managed at the local level. A coordinated planning effort involving local governments (counties and municipalities) in the watershed, agricultural agencies, DWQ and a broad range of other stakeholders will be critical if conditions in upper Conetoe Creek are to be improved. This effort must include the development of a long-term vision for protecting and restoring the watershed, as well as the specific work that will be necessary to support a patient approach to planning and implementing projects to move toward that vision.

8.4 Summary of Watershed Strategies for Conetoe Creek

The following actions are necessary to address current sources of impairment in Conetoe Creek. The intent of these recommendations is to describe the types of actions necessary to improve conditions in the Conetoe Creek watershed, not to specify particular administrative or institutional mechanisms for implementing remedial practices.

1. The appropriate agricultural agencies (including the NC Department of Agriculture and Consumer Services, the NC Division of Soil and Water Conservation, local Soil and Water Conservation Districts, and the US Department of Agriculture Natural Resources Conservation Service), in cooperation with university researchers (e.g., the NCSU Cooperative Extension Service), local farmers and DWQ, should evaluate current pesticide usage and application practices in order to better understand the dimensions of pesticide impacts in the Conetoe Creek watershed. The results of this investigation, which may require additional water sampling, should be used to determine what specific actions are necessary to reduce pesticide impacts.
2. Future clearing and snagging operations should generally be confined to removing major blockages of the stream channel. Edgecombe County Drainage District #2, NRCS and DWQ should work to develop clearing and snagging guidelines for Conetoe Creek that will provide for improved in-stream habitat while still ensuring adequate drainage. Training and oversight of contractors should be one component of this effort.
3. For any clearing and snagging operations requiring a Section 401 Water Quality Certification (necessary where a Section 404 permit is required from the US Army Corps of Engineers), DWQ will closely examine potential impacts on aquatic habitat and work to ensure that these impacts are minimized.
4. The reestablishment of woody riparian vegetation (or herbaceous cover where woody vegetation is impractical) should be encouraged along intermittent and perennial streams where such vegetation is currently lacking. In addition to supplying woody material to the

stream, properly functioning riparian areas can also serve to reduce inputs of nutrients and other pollutants. Ballahack Canal, which has the most impacted riparian areas in the study area, should be a priority area for these efforts in order to ensure an adequate supply of woody material to this tributary stream. Establishment of forested riparian buffers would receive substantial nutrient reduction credit under the Tar-Pamlico agriculture rule and is a cost shared practice under several programs.

5. Nutrient reduction efforts in the Conetoe Creek watershed will proceed most efficiently if they are coordinated with the ongoing efforts to reduce nutrients under the Tar-Pamlico Agriculture Rule. The Local Advisory Committees (LACs) responsible for implementing this rule in Edgecombe, Pitt and Martin Counties should give the Coneote Creek watershed priority status for the implementation of nutrient reduction measures.
6. The LACs within the Conetoe Creek watershed will be developing specific nutrient reduction strategies by August 2003 to meet goals under the Tar-Pamlico Agriculture Rule. While DWQ does not wish to short circuit this process, it is important that the LACs operative in the Conetoe Creek watershed consider the following factors in developing nutrient strategies:
 - Many field ditches in the watershed lack adequate vegetative buffers. Increased use of vegetative filter strips, riparian herbaceous cover, field borders or other practices along these ditches would have a high potential for reducing nutrient inputs. Riparian forest buffers, where they would not impede irrigation practices, would both provide greater nutrient removal than herbaceous buffering practices and serve as a source of woody debris for channel habitat. Cost share is available for all of these practices.
 - The use of controlled drainage is common in the watershed, but the manner in which these structures are managed merits evaluation to determine if opportunities exist to improve water management in order to reduce nutrient exports that are compatible with agricultural production goals.
 - The short-term rental of much of the cultivated land in the study area may be a disincentive for the implementation of some BMPs and will need to be addressed. Outreach efforts to educate landowners regarding the importance of nutrient management and environmental stewardship more generally should be encouraged and supported. For some structural BMPs, it may be important for LACs to provide guidance to renters on the types of arrangements to establish with owners, for example arrangements similar to those used in permanent agreements under CREP (Conservation Reserve Enhancement Program).
7. On-stream impoundments and irrigation withdrawals may exacerbate the impacts of nutrient and organic loading on dissolved oxygen levels in Conetoe Creek. The construction of new on-stream impoundments and the withdrawal of additional irrigation water should be discouraged until a study of the impacts of these activities on streamflows and dissolved oxygen levels can be completed.

Section 9

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